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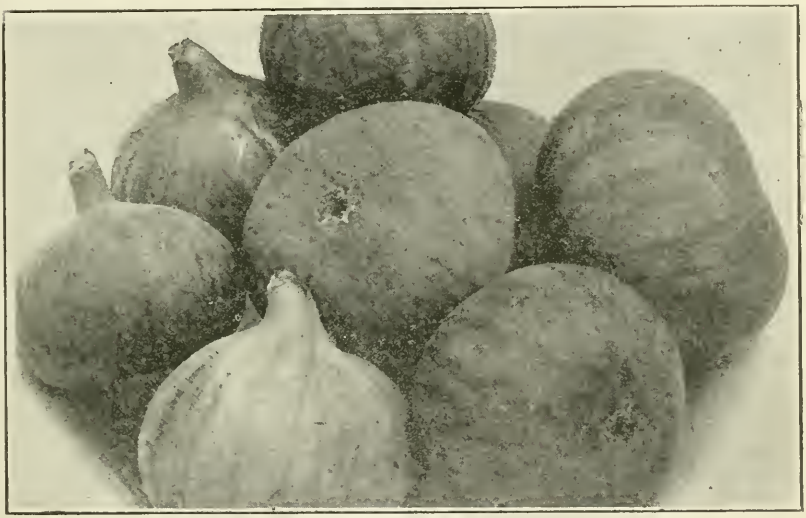

A group of Smyrna (Calimyrna) figs.

Practical Fig Culture in Arizona

By W. H. Lawrence

Tucson, Arizona, June 1, 1916

No. 77-84

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AGRICULTURAL EXPERIMENT STATION

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PLATE I.—A young but healthy fig orchard.

Practical Fig Culture in Arizona

By W. H. Lawrence

INTRODUCTION

The importance of the fig as a fruit crop in Arizona is shown by its presence in nearly all localities in which it will endure the winters and survive the frosts of spring. In addition to being a valuable fruit it serves as an excellent shade tree. The fig is a food fruit. Containing an average of more than 50 per cent sugar and 3.5 per cent protein, it is probably the most valuable of all dried food fruits, of which the fig, apple, peach, raisin, and date are the most common. The dried fig has a mildly laxative action and is not injurious when eaten in large quantities.

At the close of a study pursued during two consecutive years, the writer was impressed with the following facts: (*a*) A proper selection of varieties will make fig culture possible in a wide range of climatic, water, and soil conditions such as cover a large proportion of the agricultural area of the State. (*b*) Where limiting factors of production are almost nil and commercial production is possible, economic methods are not practiced in the growing or the distribution of the fruit on local and distant markets. (*c*) Few people appreciate the food value of the fruit and its many possible uses in either a fresh or a preserved condition.

This publication brings together the results of a general field survey, conducted by the writer in person and by correspondence, to determine the general distribution of the plant, to locate the hardy forms that have survived through a decade or more of planting, to determine the number of groups represented and the cultural management required. It also includes the results of a study pursued for three consecutive seasons on 60 trees representing a total of 43 horticultural forms belonging to 5 botanical varieties. This study was made primarily to determine the most desirable forms and varieties to be propagated and disseminated for the purpose of producing larger and more uniform yields of fruit for home use and for the market. The results of this study are given in

detail as experiments and observations, or appear as discussions and recommendations necessary to the intelligent propagation and economic management of the fig.

REASONS WHY FIG PLANTING SHOULD BE INCREASED

Arizona has a population of approximately two persons per square mile of territory. A large proportion of these live in towns and villages located many miles apart. Rural population outside the highly developed irrigated areas is scattered, usually as isolated families on ranches. Means of communication are, moreover, limited, except along the main-line railroads. With a fair proportion of the people widely scattered and for the most part long distant from shipping centers, the distribution of food products becomes an important problem. In many cases the method of transportation and distribution prohibits the handling of perishable products. This usually means a limited diet, for the greater portion of the year at least. In the absence of an adequate supply of fresh fruit during the season in which this kind of fruit should be used, the writer is convinced of the value of a study that may lead to a wider dissemination of the fig plant and to an increased use of its fruit both in a fresh and preserved condition.

CHARACTER OF FIG-PRODUCING SECTIONS

The greater portion of southeastern Arizona is comparatively low in elevation, with nearly parallel mountains extending northwest to southeast, ranging in height from 1,000 to 3,000 feet and separating comparatively level valleys lying between them. The soil of these valleys has been built up of alluvial deposits from the eroded mountains and is very fertile. The lower parts of this territory are the areas along the Colorado and Gila Rivers. In the broad valleys, low-lying mesas and their prolongations into the higher elevations of the southeastern and south central portions of the State, irrigation has made it possible to build a veritable paradise. The character of the soils and the application of water provide conditions suitable for the successful growth of many temperate and subtropical horticultural plants.

The eastern and more northern portions of the State form plateaus ranging in elevation from 4,000 to 6,000 feet, and in the northern part some of the mountains are much higher.

The varied topography induces perhaps the greatest diversity in climate of any State. Over the lower elevations intense heat

prevails, little precipitation occurs, sunshine is almost continuous, and the relative humidity is very low.

Temperatures.—Over the low elevations, which are confined mainly to the southwestern portion of the State, and which include the valleys of the lower Colorado and lower Gila rivers, the climate is arid and the range of temperature between day and night is considerable. The heat of summer is torrid, frequently rising above 100° F. and at rare intervals to as much as 120° F. in the shade. Over the lower portions of this area the temperature seldom reaches the freezing point and frosts are rare. At higher elevations, and especially in the plateau sections where air drainage is restricted, the clear sky intensifies radiation and the temperatures of spring frequently drop below the freezing point. At extreme elevations the temperature may fall below zero.

The following data are introduced in order to show the variations that occur from season to season or during a single season.

TABLE I.—MEAN, LOWEST, AND HIGHEST TEMPERATURES; EARLIEST DATE OF KILLING FROST IN AUTUMN AND LATEST IN SPRING; YEAR, AND RANGE OF DAYS IN GROWING SEASON IN EIGHTEEN WIDELY SCATTERED SECTIONS IN WHICH FIG TREES PRODUCE CROPS.

Station	Highest temperature	Lowest temperature	Mean temperature	Earliest killing frost	Latest killing frost	Length of growing season			
						Year	Min. no. of days	Year	Max. no. of days
Aztec.....	125	15	72.8	Nov. 17	Mar. 12	1909	254	1900	364
Mohawk...	126	22	75.4	Dec. 5	Feb. 14	1908	308	1904	366
Parker....	127	9	70.4	Oct. 26	Apr. 6	1897	223	1901	310
Yuma.....	120	22	72.1	.....	.....	all	365	all	365
Buckeye...	121	11	67.7	Oct. 22	Apr. 6	1906	203	1910	307
Gila Bend.	120	11	71.5	Nov. 16	Mar. 13	1899	227	1907	347
Phoenix...	117	16	69.7	Nov. 9	Mar. 31	1897	222	1901	335
Mesa.....	119	9	68.6	Oct. 21	Apr. 2	1906	202	1900	317
Tempe....	119	12	68.2	Oct. 23	Mar. 3	1910	308	1906	334
Tombstone	107	9	62.3	Oct. 22	Apr. 12	1906	235	1910	305
Nogales...	110	10	62.0	Oct. 15	May 19	1902	189	1903	241
Willcox....	110	2	59.0	Oct. 15	May 27	1906	166	1901	253
Huachuca..	105	0	60.9	Oct. 17	May 9	1908	186	1903	279
Bisbee	101	8	60.0	Oct. 22	Apr. 30	1893	152	1910	306
Casa Grande	115	8	68.4	Oct. 8	Apr. 5	1906	189	1910	315
Maricopa..	126	8	69.6	Oct. 22	Apr. 4	1909	246	1900	321
Thatcher..	113	9	62.6	Oct. 6	May 7	1909	155	1906	207
Tucson....	112	6	66.7	Oct. 19	Apr. 18	1897	208	1893	306

A study of the data shows the mean temperature to range from 59.0° at Willcox to 75.4° at Mohawk, the lowest temperature to range from 0° F. to 22° F.; the highest temperature to range from 101° F. to 127° F., with a general average of approximately 111° F.; the earliest date of killing frost in autumn to vary from October 6 at Thatcher to December 5 at Mohawk; general killing frosts rarely if ever occur except in the valley lands; the latest frost in spring varies from February 14 at Mohawk to May 27 at Willcox; and the length of the growing season varies at each station with wide ranges in duration of growing season at the same stations in different years.

Considering temperature as a limiting factor, the data in Table I show the Lower Colorado Valley and mesa country and the Salt River Valley to be quite free from dangerous temperatures; and for most years the growing seasons, measured in the number of days from the last killing frost in spring to the first killing frost in autumn, are phenomenally long. Within these areas are many thousands of acres of land well adapted to fig culture, being not only frostless but nearly rainless. Throughout these areas the Smyrna fig, when caprified, should produce satisfactory returns in most seasons. Throughout the higher elevations where the climate is more severe, with the possible exception of a few small isolated areas, the Adriatic type is the more desirable form.

Precipitation.—Precipitation occurs principally during two portions of the year, a summer maximum during July to September and a secondary maximum during the colder portion of the year. During April, May, and June the area is practically rainless and but little occurs during the late autumn months. In the eastern half of the State the rainfall varies from 10 to 25 inches per year, while in the western section precipitation varies from 1 to 10 inches. Rainfall increases with the elevation. The character of the precipitation, the time of occurrence, the distribution during the several periods of the year, the amount each month, and the varying periods of heavy and light precipitation are questions of vital importance in the production of the fig. The following data compiled from various sources show the character of the precipitation occurring at several places in the State where the fig is being grown.

TABLE II.—LOCATION, ELEVATION, LENGTH OF RECORD, MEAN ANNUAL PRECIPITATION, AND RANGE OF VARIATION FROM LOWEST TO HIGHEST, AND THE YEAR IN WHICH THE EXTREMES OCCURRED FOR TWENTY WEATHER BUREAU STATIONS.

Station	Elevation (feet)	Length of record (years)	Range of variation						Mean annual precipitation (inches)
			Highest		Next highest		Lowest		
			Year	Inches	Year	Inches	Year	Inches	
Aztec.....	492	12	1905	13.57	1908	7.55	1901	1.12	4.35
Mohawk...	538	6	1905	6.49	1886	4.13	1895	0.10	3.17
Parker.....	353	19	1905	9.58	1912	6.55	1900	2.09	4.83
Yuma.....	141	35	1905	11.41	1909	8.63	1899	0.60	3.26
Buckeye...	980	23	1905	21.80	1896	9.50	1891	0.63	7.22
Gila Bend.	737	12	1896	10.21	1908	7.69	1900	2.55	5.67
Phoenix...	1,108	20	1905	19.73	1911	14.12	1885	3.77	7.39
Mesa.....	1,244	19	1905	20.31	1911	13.82	1900	5.10	9.10
Tempe....	1,165	11	1905	22.15	1911	14.45	1910	6.02	11.01
Benson....	5,532	12	1905	22.58	1896	16.78	1885	4.24	9.35
Tombstone	4,550	17	1905	27.84	1907	19.31	1910	11.77	14.54
Cochise....	4,250	7	1905	22.27	1896	16.03	1900	1.30	11.41
Willcox....	4,205	12	1905	23.52	1884	18.38	1897	5.66	10.67
Huachuca..	5,100	30	1905	36.97	1907	16.96	1910	9.54	16.86
Bisbee.....	3,523	20	1898	25.87	1907	23.59	1910	12.85	18.05
Clifton....	3,584	6	.....	.....	1898	16.14	1910	8.67	13.16
Casa Grande	1,396	....	1905	19.52	1899	10.21	1885	2.02	6.06
Maricopa..	1,180	13	1905	13.51	1912	8.89	1882	0.38	6.06
Thatcher..	2,800	17	1905	17.38	1913	12.83	1902	4.73	10.08
Tucson....	2,425	30	1905	24.17	1889	18.37	1885	5.26	11.58

Since nearly ripe fruit is usually ruined by moisture, no rainfall and dry air are desirable during the ripening and picking season. A glance at the above data shows that the annual rainfall varies greatly for each section and that occasional extremely wet seasons occur. Seasonal distribution of rainfall is the important factor in fig production. The normal annual rainfall chart appearing below, is useful in giving correct information concerning the usual distribution and precipitation for sections in which the Smyrna and less hardy forms may be grown.

In those sections where Adriatic forms are adaptable for home use occasional summer rain does no appreciable injury, since immediate attention is given to the collection and use of the fruit. At higher elevations where the summer rainfall is considerable,

neglected plantings of a decade or so still survive and produce some fruit without care. In such localities a greater use of the fig would be possible if it were given attention and protection.

GENERAL FIELD SURVEY

Through correspondence and a personal general field survey, the approximate distribution of fig trees now growing throughout the State has been determined, as follows:

In Nogales there are several small trees of a black variety that bear one crop each year.

At Garces there are several large, fine trees of the so-called small

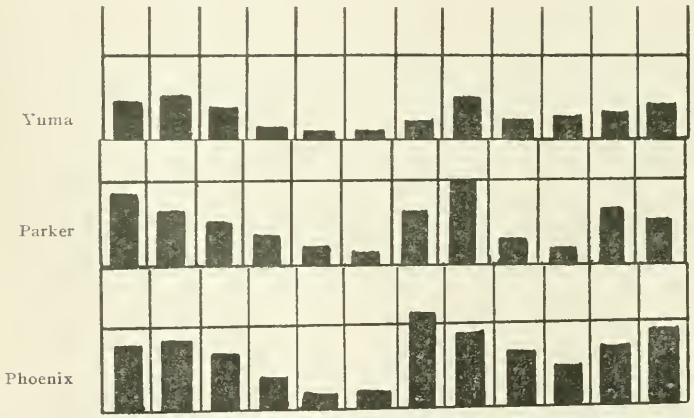

Fig. 1.—Diagram showing the comparative monthly distribution of rainfall in fractions of an inch, for Yuma and Parker, located in the southwestern lowlands, and Phoenix, in the middle section, embracing the Salt River and Gila River Valleys.

Black Mission. Brown Turkey is also being tested. In this immediate locality the more or less protected places in the foothills and mountains, where air drainage is good, provide the best situations for fig growing.

At Roosevelt there are four small trees, five to six years old. These produce green fruit throughout the season, but the crop falls before it ripens. They are probably Smyrna trees.

At Tucson the Brown Turkey produces one good crop each year, ripening the fruit for approximately 40 days, during July and August. Both black and white forms of the Adriatic group, also quite common in this section, are less important. Winter weather severe enough to kill the younger growth, less frequently the entire top, occurs, yet pruning away the dead stems allows new wood to form on which a fair second crop of fruit may develop.

There is a small home-garden fig orchard at Hackberry on the Colorado River (Gregg's Ferry).

In the Gila River Valley at Solomonville and Thatcher both white and black fig trees are found. These plants range up to 30 years in age and bear two to three crops each year. The black variety is perhaps the more desirable since it produces fruit through a longer season of the year.

In Clifton and adjacent territory both black and white figs are grown. Even at this elevation (3,584 feet), two and occasionally three crops are produced, maturing over a period of 40 to 60 days, the first ripening early in August. Smyrna trees are also reported growing in Clifton. Well matured, locally grown figs are sold at 12 cents a pound wholesale.

Fig. 2.—Results of the 1912–1913 freeze. View of the 60 trees planted in two rows on the Experiment Station Farm near Phoenix. Attention is called to the fact that the 30 trees located in row B were killed to the ground and but few of them have partially recovered. The row has the appearance of sticks set in the ground. Attention is also called to the presence of two specimens barely alive in row A while there are several large kealthy plants. Photograph by W. H. Lawrence.

At an elevation of 5,000 feet in the Dragoon Mountains, both black and white figs produce two and three crops annually, the ripening period continuing from July to November, while frosts destroy the fruit at lower elevations where air drainage is restricted.

Fig trees of a white variety, very old but thrifty and large, are also located in the Huachuca Mountains at elevations up to 5,000 feet. Stock from this variety has passed the winter successfully in the Sonoita Valley without protection, where even more severe winter weather occurs. In the Sonoita Valley there are also black and white fig trees several years old which produce fair crops.

Throughout the Sulphur Spring Valley the Mission and White Adriatic are the leading varieties. Old trees bear two crops each year, ripening until the advent of freezing weather. A purple fig grown and distributed from Safford also comes in two crops, ripening until the green fruit is destroyed by frost. A fine tree of the black variety is also reported from Tombstone. Smyrna figs have been planted at Gleeson, and while they endure the winter and set fruit, none matures due to lack of pollination. A small white variety about 10 years of age, located near Willcox, now bears two to three crops each year, producing almost continuously from the last frost in spring to the first frost in autumn.

Several large fig trees are standing in the streets of Bisbee.

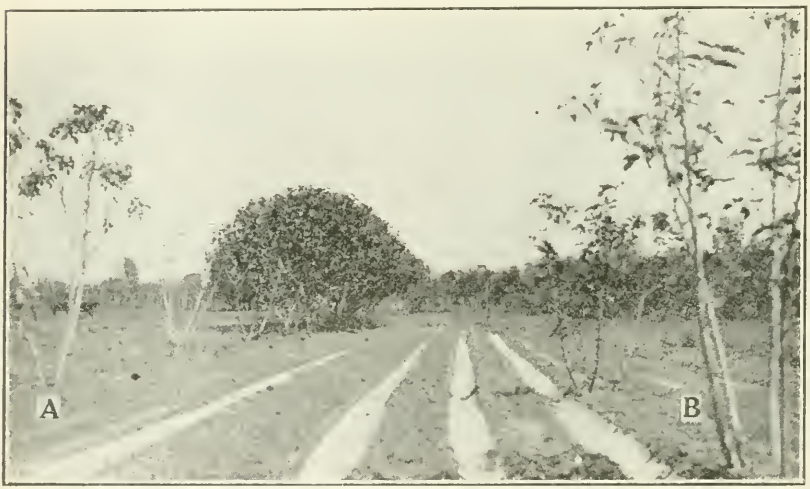

Fig. 3.—View showing last 40 trees in rows A and B, Fig. 2. Note the poor condition of the trees in row B, also the vacant spaces; and the three weak trees in row A with a second group of healthy plants in the distance.

In the Lower Verde River country, at an altitude of 3,315 feet, a small white fig endures the winter, while a black variety grown in the same location freezes to the ground. Two crops are produced each year.

Along the Upper Verde River, Angelique (white), San Pedro and Mission (black) bear annually, but usually both the earliest and latest figs of the first and last crops are destroyed by frosts The white variety endures the conditions up to 4,500 feet elevation, while the black sorts prove less hardy. With protection, plants are easily carried through the winter, even at an elevation of 5,800 feet.

The production of figs in both the valley and the mesa country near Yuma is limited to a few varieties of Adriatics. These include both light and dark-colored forms. Most of the plantings are old. The names of the varieties, dates of planting, and sources of stock have been lost through the exchange and sale of property. In both mesa and valley the fig believed to be the Black Mission is the leading sort, since it excels in carrying capacity, which makes it possible to ship the fruit long distances. Two crops are produced. The tree should bear commercial crops at 4 to 6 years of age. On the mesa, the first ripens 8 to 12 days earlier than on the valley floor, where picking begins May 20 to 25. The crop is in demand as fresh fruit in Los Angeles and San Francisco markets at prices ranging from 50 to 75 cents per pound. By the time the first fruit produced in the valley is ready for shipment, however, the price usually drops to 12 to 20 cents in these distributing centers. This fruit is shipped in 7-pound crates. A yield of 5 to 20 crates is secured per tree. The second crop begins to ripen July 7 to 12 and continues for about three weeks. The fruit is put up in two grades, selling at about 9 cents and 5 cents, respectively. On trees 10 to 15 years of age, the yield varies from 10 to 35 crates. Of the other varieties mentioned, both light and dark-colored, several are larger then the Mission but are too soft to ship, yet even these are of great value for canning or drying. Fig trees grown in this section of the State are mostly located along ditch banks, and receive no cultivation or irrigation, yet return enormous profits.

At Mesa, in the Salt River Valley, occurs the so-called Black Adriatic, which is the sole representative of commercial sorts grown in the immediate locality. This variety produces two crops, the first ripening about June 10. It is shipped to various markets—San Francisco, Denver, El Paso, and intermediate points. The grower receives 4 cents per pound. The second crop ripens July 25 to August 1. For the most part it is consumed locally for canning, selling as fresh fruit at 2 cents per pound. Trees grow without care along banks of irrigation canals.

On the Experiment Station Farm near Phoenix is a small orchard of approximately 60 trees of various varieties. Half the orchard was planted in 1904 and the balance in 1909. Details concerning these trees are given elsewhere in this paper.

SCOPE OF FIG GROWING

Figs, no doubt, have been grown in Arizona for more than a hundred years. Numerous forms have been generally disseminated

throughout the warmer portions of the State. Even the casual observer notes that many varieties find conditions congenial to vegetative growth, while many produce annual yields of well matured fruit. As early as 1899 fig production had become an important line of fruit raising. The Twelfth United States Census shows 4,325 trees of bearing age, and a yield of 949,140 pounds. The Thirteenth Census, however, shows a total of 3,848 trees in bearing, a decrease of nearly 10 per cent, with a much greater decrease in average yield per tree.

There are no commercial orchards in the State. Less than 400 farms have bearing trees, the average number of trees per farm being approximately 10. These trees are generally located in the home orchard, the lawn, or along the irrigation ditch.

The following data, adapted from the Thirteenth United States Census, is of more than usual interest and is introduced at this point to show clearly the success met with in planting trees at earlier dates, the results secured from older plantings, and the development of fig growing in sections where very promising returns have been realized.

TABLE III.—SHOWING THE NUMBER OF BEARING AND NON-BEARING FIG TREES, INCREASE IN PER CENT OF PLANTINGS, TOTAL AND AVERAGE YIELD FOR ALL COUNTIES, 1910.

Counties	Trees bearing	Total yield	Average yield	Trees non-bearing	Increase in last 10 years
	Number	*Pounds*	*Pounds*	*Number*	*Per cent*
Apache	.....	.....	.....	.....	.....
Cochise	76	785	10.3	5	6.6
Coconino	.....	.....	.....	.....	.....
Gila	37	10,655	287.9	.....	.....
Graham	190	3,236	17.0	215	113.2
Maricopa	2,628	96,540	36.7	44,694	1,700.7
Mohave	70	630	9.0	.....	.....
Navajo	.....	.....	.....	.....	.....
Pima	344	650	1.8	.....	.....
Pinal	164	5,800	35.4	113	70.1
Santa Cruz	2	200	100.0	.....	.....
Yavapai	60	3,100	51.6	58	96.6
Yuma	277	5,485	19.8	2,123	776.4
The State	3,848	127,081	33.0	47,208	1,226.8

The above table is instructive since it shows that conditions in Apache, Coconino, and Navajo Counties inhibit the growing of the

fig plant. Also, while older plantings have endured the conditions of climate and soil, increased plantings in Gila, Mohave, Pima, and Santa Cruz Counties have not been successful, yet in some parts of Graham, Maricopa, Pinal, Yavapai, and Yuma counties conditions are favorable to production on a commercial scale. It is to be noted that of the four counties in which no young trees are reported, Santa Cruz and Gila counties report average yields of 100 to 287.9 pounds per tree. It is apparent that plantings can be increased through the use of hardy stock. An inspection of the data will show increased plantings of 6.6 per cent to 1,700 per cent for different counties.

INVESTIGATIONS IN SALT RIVER VALLEY

A major portion of the investigations was conducted in a small orchard of several varieties of figs located on the Experiment Station Farm at Phoenix. There were 60 trees; 30 were planted in 1904, the remainder in 1909. The following table gives data relative to the orchard and its condition at the close of the 1915 growing season.

TABLE IV.—NUMBER OF STANDARDS, HEIGHT AND SPREAD OF TOPS, CONDITION OF THE PLANT, GROWTH OF NEW SHOOTS AND SUCKERS OF 43 VARIETIES OF FIGS, 1915.

Variety	Number of stems	Height of top	Spread of top	Condition of plant	Growth new shoots	Average length suckers
		Feet	*Feet*		*Inches*	*Inches*
Cernica	1	4.5	2	Good	2.5	12
Mission, Black	1	22	30	Very good	12	.....
Mission, Black	3	17	19	Good	5	.....
Rose Blanche	1	11	14	Fair	8	.....
Bourjassote Panache	2	12	7	Good	30	48
Magnolia	1	7	7	Very poor	1	.....
Magnolia	3	8	6	Poor	2.5	.....
Bardajic	1	17	22	Very good	15	.....
Capri Milco	1	10	7	Good	12	72
Capri Milco	4	10	8	Fair	10	.....
Capri Milco	4	2	3	Fair	12	6
Capri Milco	1	8	5	Good	6	4
Capri Milco	4	8	5	Good	.....	.....
White Adriatic	2	15	23	Good	5	.....
White Adriatic	1	15	26	Very good	4	.....
Capri No. 1	1	16	26	Very good	3	.....
Capri No. 1	1	12	15	Very good	8	.....

TABLE IV.—NUMBER OP STANDARDS, HEIGHT AND SPREAD OF TOPS, CONDITION OF THE PLANT, GROWTH OF NEW SHOOTS AND SUCKERS OF 43 VARIETIES OF FIGS, 1915—Continued.

Variety	Number of stems	Height of top	Spread of top	Condition of plant	Growth new shoots	Average length suckers
		Feet	*Feet*		*Inches*	*Inches*
Capri No. 2	1	10	8	Good	4	48
Capri No. 3	1	10	7	Good	15	84
Capri No. 3	2	9	9	Good	6	60
Capri Magnissalis	2	5	3	Good	7	60
Capri Magnissalis	4	7	3	Good	6	42
Capri Magnissalis	4	5.5	3	Good	8	30
Maslin Capri No. 143	4	.....	.....	.....	.....	.....
Maslin Capri No. 91	4	.....	.....	.....	8	80
Capri Elanford	1	8	6	Good	12	48
Agen	2	8	7	Good	6	.....
White Endich	4	8	6	Good	30	.....
San Pedro White	5	8	6	Fair	5	.....
Checker Injir	3	11	7	Good	24	.....
Black Smyrna	1	14	19	Very good	6	.....
Black Smyrna	1	14	19	Very good	10	.....
Lob Injir	1	15	19	Very good	12	.....
Lob Injir	1	15	9	Very good	15	.....
Lob Injir	1	15	9	Very good	15	.....
Bellona	1	8	3	Very good	6	.....
Black Ischia	3	11	8	Good	30	6
Green Ischia	3	6	4	Good	3	12
Madeleine	4	8	5	Good	18	60
Doree	4	8	3	Good	24	54
Genoa	3	13	10	Good	15	60
Blue Genoa	1	10	5	Good	18	36
White Genoa	4	7	4	Good	6	30
Negro Largo	3	9	5	Good	12	48
Lemon	1	13	10	Good	3	48
Royal Vineyard	4	7	5	Good	6	36
Verdal Longue	3	.....	.....	.....	.....	.....
Angelique	4	11	7	Good	6	24
Coldi Signora Nigra	4	8	4	Good	10	24
Drap d'Or	6	4	3	Good	6	36
Dauphine	3	10.5	8	Good	15	48
Ronde Violette Hative	4	7	4	Good	10	60
Ringo Del Mel	1	9	7	Good	12	60
Hirta du Japon	2	7	4	Good	8	36
Salmo Sambach	3	17	22	Good	.....	.....
Bulletin Smyrna	1	32	43	Very good	.....	.....
Black Adriatic	1	13	16	Good	.....	.....
Black Adriatic	1	13	16	Good	.....	.....

The table does not show the missing trees. The varieties that have been removed are White Neri, Salmo Sambach, Celestial, Maslin Capri No. 43, and one tree each of Maslin Capri No. 91, Capri Milco, and Capri Elanford.

The orchard had been trained to a single standard. There are at this time the Cernica, Mission, Rose Blanche, Magnolia, Capri No. 3, Capri Milco (two trees), Bardajic, Capri No. 2, Salmo Sambach, Capri No. 1, Lob Injir, Black Smyrna, Lemon, Bulletin Smyrna, and Black Adriatic that have not been killed back to the root. The remaining varieties are now producing two to six standards—mostly three to four. Table IV gives the number of stems for each plant, condition of the plant, together with height and spread of top, and length of new growth. These data give a good idea of the comparative hardiness of individual trees.

Fig. 4.—View of the third section of 2 trees. Note condition of the trees in row B, and group of weak trees with a third lot of healthy plants. To the left of row A and in the background may be seen a large specimen of Bulletin Smyrna which is also free from winter injury. From photograph taken by W. H. Lawrence.

Influence of temperature.—The condition of the plants is largely due to the severe weather occurring from December 26, 1912, to January 15, 1913, which was conspicuously abnormal. The following table shows the character of the weather for that period.

TABLE V.—SHOWING THE HOURLY TEMPERATURES, HOURLY WIND VELOCITY, AND HOURLY WIND DIRECTION FROM DECEMBER 26, 1912, TO JANUARY 15, 1913, INCLUSIVE

Date		A. M.												P. M.										
		1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Mid-night
1912	Temperature.	41	43	47	41	43	41	36	39	43	48	53	54	55	57	58	58	57	53	49	48	47	43	43	38
Dec.	Velocity....	2	3	8	6	6	2	5	2	4	3	4	3	4	4	4	4	3	5	4	2	2	1	2	3
26	Direction....	SW	W	N	N	N	SE	S	E	N	W	W	SW	W	NW	NW	NW	W	NW	NW	NW	SW	SW	E	NW
	Temperature.	37	43	39	43	44	38	32	36	43	53	57	60	63	64	65	64	63	60	55	53	53	52	48	46
27	Velocity.....	1	2	4	4	5	4	3	2	3	2	7	8	7	1	6	4	2	1	2	4	7	6	3	5
	Direction....	NW	NW	NE	NE	NE	NE	NW	NW	SW	NW	NE	NE	NE	NE	E	E	E	E	E	E	E	E	E	E
	Temperature.	46	46	46	44	34	38	32	35	42	50	55	57	60	58	61	61	58	55	52	48	46	45	43	40
28	Velocity.....	5	4	5	4	2	1	2	1	2	4	7	5	3	2	3	2	3	2	2	3	1	2	2	4
	Direction...	E	E	E	E	W	W	W	NW	E	E	E	E	SE	W	NW	SW	W	W	W	W	N	W	S	NW
	Temperature.	37	38	33	30	31	34	30	31	33	42	46	52	57	59	60	61	59	56	50	48	40	43	40	39
29	Velocity.....	2	1	2	2	2	3	5	2	1	3	3	2	2	2	4	3	2	2	2	3	1	2	3	4
	Direction....	W	E	E	N	E	E	E	E	E	E	SE	SE	N	S	SW	W	W	W	E	N	E	E	E	E
	Temperature.	37	37	36	36	36	36	33	34	37	42	48	53	57	60	61	62	60	56	53	49	45	43	40	39
30	Velocity.....	6	5	4	6	5	5	4	2	2	5	1	3	2	2	3	2	1	2	2	2	2	2	3	3
	Direction....	E	NE	E	E	E	SE	E	SE	NE	E	SE	S	SE	SE	SE	S	SW	W	W	NE	NE	E	SE	SE
	Temperature.	37	37	35	32	35	36	33	34	39	45	54	57	60	63	62	64	61	58	55	50	47	46	44	41
31	Velocity.....	3	3	3	3	5	5	5	3	6	4	4	4	4	2	2	3	2	1	1	2	1	2	2	4
	Direction....	E	E	SE	NE	NE	E	E	E	E	E	E	SE	E	SE	SW	SW	S	S	NW	N	NW	E	E	SE
1913	Temperature.	41	42	38	36	37	38	35	34	38	45	54	57	62	63	65	65	63	59	57	53	52	48	44	43
Jan.	Velocity.....	4	5	2	4	3	4	2	4	2	2	2	2	3	3	3	3	3	3	4	1	3	2	2	3
1	Direction....	E	E	E	E	SE	E	E	SE	E	NE	SE	SW	W	SW	W	W	W	W	N	NE	E	SW	SE	E

TABLE V.—SHOWING THE HOURLY TEMPERATURES, HOURLY WIND VELOCITY, AND HOURLY WIND DIRECTION FROM DECEMBER 26, 1912, TO JANUARY 15, 1913, INCLUSIVE.—Continued.

Date		A. M.												P. M.										
		1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Mid-night
1913 Jan. 2	Temperature.	43	42	40	41	40	40	41	40	43	48	57	60	62	63	64	65	64	60	57	52	49	49	44	42
	Velocity.....	3	3	2	3	2	3	2	2	3	1	2	4	2	5	4	3	2	1	2	2	3	4	3	2
	Direction....	E	S	S	SE	N	NW	W	S	SW	NW	SW	SE	NW	W	W	W	W	W	E	S	NE	NE	E	E
3	Temperature.	40	39	39	39	39	36	34	32	40	46	56	60	63	64	67	65	64	62	56	54	49	47	46	44
	Velocity.....	2	6	4	3	1	2	1	3	4	4	5	4	3	2	3	4	3	1	3	2	2	4	5	5
	Direction....	SE	E	E	E	E	SE	E	NE	E	E	E	E	E	N	W	NE	NW	NW	N	SE	SE	E	E	E
4	Temperature.	40	42	40	39	38	35	35	34	38	46	52	57	59	62	63	64	60	56	52	50	48	45	43	42
	Velocity.....	7	8	6	4	5	2	3	2	5	3	7	5	4	3	6	10	15	14	13	12	16	12	11	9
	Direction....	E	E	E	E	E	N	N	SE	E	E	E	E	NE	NW	W	W	W	W	NW	W	W	W	W	W
5	Temperature.	40	39	37	35	34	33	28	29	30	34	37	38	39	39	41	40	39	37	34	33	30	28	27	27
	Velocity.....	8	7	7	6	6	6	5	6	8	9	7	7	9	8	8	7	7	4	3	2	4	2	1	1
	Direction....	W	W	W	W	W	W	SW	W	SW	SW	SW	W	SW	W	SW	SW	SW	W	SW	SW	SW	W	W	SW
6	Temperature.	25	23	21	19	17	18	17	18	20	26	30	34	36	38	39	39	36	34	31	31	29	27	26	24
	Velocity.....	3	2	3	4	4	1	1	1	2	3	5	6	6	7	8	9	10	6	4	4	3	3	2	2
	Direction....	SW	E	E	E	E	SE	NE	W	SW	SW	W	W	W	SW	SW	SW	SW	SW	SW	SW	SW	SW	E	NE	SE
7	Temperature.	21	23	18	19	19	20	16	17	23	29	35	36	38	39	40	41	39	37	34	32	31	30	28	23
	Velocity.....	2	1	3	3	2	2	2	1	3	3	2	3	3	4	3	3	3	3	3	3	2	3	1	3
	Direction....	N	NW	E	NE	E	E	E	NE	NE	S	S	SW	NW	SW	W	NW	W	W	W	W	SW	SW	SW	N
8	Temperature.	24	23	22	21	19	22	23	21	27	34	40	47	49	50	52	52	51	49	45	42	39	39	39	38
	Velocity.....	2	2	1	1	3	2	2	3	2	1	4	10	10	10	6	4	2	1	1	1	2	4	5	6
	Direction....	S	E	E	N	NE	N	S	S	SE	S	NW	NE	E	E	E	E	NE	SE	S	S	E	E	E	SE

TABLE V.—SHOWING THE HOURLY TEMPERATURES, HOURLY WIND VELOCITY, AND HOURLY WIND DIRECTION FROM DECEMBER 26, 1912, TO JANUARY 15, 1913, INCLUSIVE—Continued

Date		A. M.												P. M.										
		1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Mid-night
9	Temperature.	37	36	36	35	36	36	35	32	39	44	48	50	53	56	57	59	57	51	48	45	43	42	36	39
	Velocity.....	6	5	4	5	3	6	7	4	2	5	8	5	4	4	5	4	3	5	2	1	1	3	2	4
	Direction....	SE	E	E	E	E	SE	E	E	E	SE	SE	SE	SE	SE	SE	SE	SW	W	W	W	SW	SE	E	NE
10	Temperature.	40	43	42	37	37	39	40	41	41	47	48	50	52	50	50	49	43	41	40	40	40	40	40	39
	Velocity.....	5	5	3	8	3	3	2	4	3	4	4	8	10	7	6	4	8	10	6	4	2	2	2	2
	Direction....	NE	E	NW	W	SE	N	E	E	E	E	SW	SW	SW	SW	SW	SW	SW	NW	NW	N	E	SE	S	E
11	Temperature.	39	38	37	35	32	34	32	33	35	37	40	43	49	46	47	49	46	45	43	41	37	37	36	35
	Velocity.....	1	2	3	5	2	2	3	2	2	2	4	4	3	3	4	4	3	4	2	3	2	4	4	3
	Direction....	SW	SW	W	W	NW	SW	NW	N	N	SW	SW	SW	SE	SE	E	SE	SE	E	E	E	E	NE	NE	E
12	Temperature.	32	32	31	30	29	29	27	28	28	34	40	46	48	50	52	53	52	50	45	43	42	40	39	36
	Velocity.....	2	1	1	3	1	3	2	1	1	3	3	3	3	2	3	3	2	2	2	3	1	1	1	2
	Direction....	E	SW	SW	W	W	W	NE	SE	E	SE	E	NE	SW	N	NE	N	NE	W	NW	N	NW	NW	NW	W
13	Temperature.	32	32	31	30	29	29	27	28	28	34	40	46	56	61	63	64	61	57	54	52	50	47	45	43
	Velocity.....	1	1	1	2	2	2	4	2	1	1	2	1	4	3	3	5	4	3	3	3	3	2	2	2
	Direction....	NE	NE	E	SE	SE	SE	E	E	E	E	SW	SW	E	SE	S	SW	W	W	NW	N	N	N	N	E
14	Temperature.	43	45	44	42	40	39	36	37	40	46	54	58	60	61	62	64	63	61	57	56	55	52	49	46
	Velocity.....	2	3	4	2	2	2	2	2	6	5	8	6	7	7	5	3	2	1	2	1	2	1	2	2
	Direction....	E	E	E	E	SE	SE	NE	E	E	E	E	E	E	E	SE	SE	SE	E	NE	N	N	SE	S	N
15	Temperature.	46	45	42	41	40	42	41	43	44	46	52	53	55	57	57	56	55	53	50	48	47	45	44	43
	Velocity.....	3	4	5	4	7	5	4	4	5	6	5	5	2	2	2	1	2	2	4	2	1	2	4	6
	Direction....	E	E	E	E	E	E	E	E	E	E	E	E	SE	SE	SE	S	S	SW	SW	W	NW	NW	SE	E

The temperatures during the 24 hours of the first and last dates more nearly represent the average and usual winter weather, the range being from 40° F. to 60° F. A study of these data shows the temperature of the air to vary from 32° F. to 65° F. during a period of 8 hours on December 27, with very variable, and lower, degrees during December 29, and from January 5 to January 13, 1913, inclusive and respectively. The lowest temperature occurring during the period was 16° F. The recurrence of low temperatures was followed by periods in which all signs of frost disappeared. Alternate freezing and thawing was undoubtedly responsible for the severe injury occurring during the interval of 21 days included in the chart.

Attention is also directed to the hourly direction and velocity of the wind. During many hours of dangerous temperatures the velocity was greater than would warrant an attempt to heat an orchard by the use of smudge pots.

This period is the coldest that has occurred here since the recording of temperature by modern methods, and as it is perhaps the coldest that will occur for many years, the conclusions drawn will be a fair guide to the influence of temperature on fig production.

Temperature has been the limiting factor in the determination of the varieties we now recommend as hardy. These forms are represented by both Capri and edible forms, and of the last named one or more forms of each type of the several groups endure the conditions. This has made it necessary to study the entire field of fig growing.

The varieties but slightly damaged by the 1912–1913 freeze are again in good condition and bearing fruit. The White Adriatic, Black Ischia, and Madeleine have this year (1915) borne fair yields of fruit, while the remaining varieties have produced none or a very light crop. Observations show that dying-back of trees year after year stunts them, while the very tender ones killed to the ground each winter do not produce fruit.

Yield of edible fruit.—Accurate yields have not been available for use except those computed from the data given in the 1909 and 1910 United States Census and those kept at the Experiment Station Farm at Phoenix. In 1899 the approximate yield per tree for 4,325 specimens of bearing age was 219 pounds. In 1910 it was 33 pounds per tree. This yield, however, is the average for all bearing trees of all ages and all varieties. A further calculation shows a range from 1.8 pounds to 287.5 pounds per tree. Taking into account only the yield from old and well established trees, the returns vary

from 100 pounds to the maximum stated. These data, for our purpose, are not misleading. Careful records of the yield of mature fruit from all the heavy yielding varieties grown in the Station orchard gave the following data:

TABLE VI.—THE 1914 AND 1915 YIELDS OF FRUIT PRODUCED BY FIVE HARDY VARIETIES GROWN IN THE STATION ORCHARD

Variety	Number of trees	1914	1915
Mission	2	200	759
Lob Injir	3	350	356
Bulletin Smyrna	1	450	615
White Adriatic	2	25	400
Black Smyrna	2	150	300

As will be observed, there are no yield records for 1913 following the severe freeze. The data taken the following years show conclusively, however, that certain varieties are not injured permanently, but recover and produce full yields after one or two years.

While the above table does not show the edible fruit (including sour fruit), the comparison does show the recovery of the tree as well as the comparative frost injury of the more hardy forms of figs.

In order to show the dates of picking and the yield per picking for the more important varieties investigated, the following table is included:

TABLE VII.—VARIETY, DATE OF PICKING, YIELD OF FRUIT PER PICKING, AND TOTAL YIELD FOR THE SEASON OF 1915

Date of picking	Varieties									
	Mission		Lob Injir			Bulletin Smyrna	Black Adriatic	White Adriatic	Black Ischia	Madeleine
	(1)	(2)	(1)	(2)	(3)					
July										
19	.....	57.5	34.5	.....	.....	.....	.....	14	.....	2
21	11	13	.....	.....	.....	.....	23.5	.....	.....	.....
22	40	20	10	4	6.5	.....	.....	25.5	2	16.2
23	.....	7	4.5	18.5	.....	.....	3	.....	.....	.....
26	39	44	54	29.5	36	.....	9	31	7.5	1.5
27	146.5	.....	.....	.....	.....	.....	.....	.....	.....	.....
29	22	32	50	14.5	13.5	.....	.....	.....	.....	.....
30	74	13.5	.....	.....	.....	.....	30	.....	7	.....
31	57.5	28.5	.....	3.5	1.5	25	.....	.....	.....	.....
Aug.										
2	28	.....	.....	.....	.....	33.5	.....	.....	3.5	.5
4	25	4.5	21	.....	8.5	11.5	.....	.....	.5	.....
6	8	.....	.....	.....	.....	72.5	.....	.....	.....	1.0
7	.....	.....	16	.....	.....	.....	.....	.....	.....	.....
9	24	5.5	11.5	5	5.5	118	.....	.....	1.5	.....
10	19	13	.....	.....	.....	50.5	.....	2.5	.....	.....
11	.....	.....	9	1.5	2	24	18	.....	.....	.....
13	15	10	.....	.....	.....	.....	.....	.....	.....	.....
17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
19	.....	.....	.....	.....	.....	20	.....	.....	.....	.....
20	.....	.....	.....	.....	.....	14	.....	.....	.....	.....
23	.....	.....	.....	.....	.....	97	.....	.....	.....	.....
26	.....	.....	.....	.....	.....	35	.....	.....	.....	.....
Sept.										
1	.....	.....	.....	.....	.....	35	.....	.....	.....	.....
2	.....	.....	.....	.....	.....	55	.....	.....	.....	.....
Later	.....	.....	.....	.....	.....	25	.....	.....	.....	.....
TOTAL	509	248.5	210.5	76.5	73.5	616	83.5	73	22	21.2

In the above table especial attention is directed to the use of the Mission and Bulletin Smyrna as a combination of two forms of figs that produce heavily and continue to bear for many weeks.

Decrease in size of fruit during picking season.—During the process of harvesting the 1915 crop, the specimens of many varieties gradually decreased in size during subsequent pickings, the exact decrease being given in the following table

TABLE VIII.—DECREASE IN SIZE OF FRUIT FOR SUCCESSIVE PICKINGS OF 13 VARIETIES, 1915 CROP, INDICATED BY THE NUMBER OF FIGS WEIGHING ONE POUND.

Variety	Dates of picking							
	July			August				
	19	22	26	3	5	9	10	21
Rose Blanche	....	....	11	....	....	25	....	38
Bourjossote Panche	10	....	12	....	....	17	....	....
Magnolia	....	....	17	....	....	40	....	....
Magnolia	....	....	12	21	....	20	....	24
White Endich	....	....	11	13	....	14	....	26
San Pedro White	....	....	8	6	....	7	....	21
Genoa	....	....	....	20	56	....	....	106
Madaleine	11	....	....	19	16	....	....	....
Doree	....	....	....	36	....	16	....	48
Negro Largo	....	....	....	9	48	20	....	....
Lemon	....	....	....	26	112	32	....	....
Angelique	....	....	....	64	27	....	....	....
Cal di Signon Nigra	....	....	....	124	64	26	....	....

In is interesting to note in this connection that the varieties included in this table fall into three groups: (1) those decreasing in size during the season; (2) those decreasing during mid-season; and (3) those increasing during the season.

Size of fruit in different crops.—One, two, and three crops were produced by different varieties, the number being determined very largely by low temperatures occurring during the winter. The first crop usually matures about the middle of July or later. Specimens found in autumn on the tips of young wood pass the winter on the naked branches of the tree and mature the following spring and are known as the Brebas. They are usually of good size and are distinguished from the second and third crop with certainty by their position on the wood of the previous season.

Only a few of the varieties on the Experiment Station Farm produced two crops in 1915. The Mission (two trees) produced 85 pounds, while the Magnolia, Black Ischia, Green Ischia, Doree, Genoa, Negro Largo, Lemon, Drap d'Or, Dauphine, and Ronde Violette Hative each produced very light crops.

Yield of Capri figs.—During the summer of 1915 all the Capri trees produced figs.

Capri Milco produced one crop, all of which fell, due to lack of caprification, and no second crop formed; Capri Magnissalis dropped a full crop from April 1 to 10; Capri No. 2 did not produce a second crop and the first fell about July 1; Capri No. 3 was represented by a good crop of figs which all fell except one specimen in which *Blastophaga* had found an entrance; and Capri No. 1 set a light second crop by July 1.

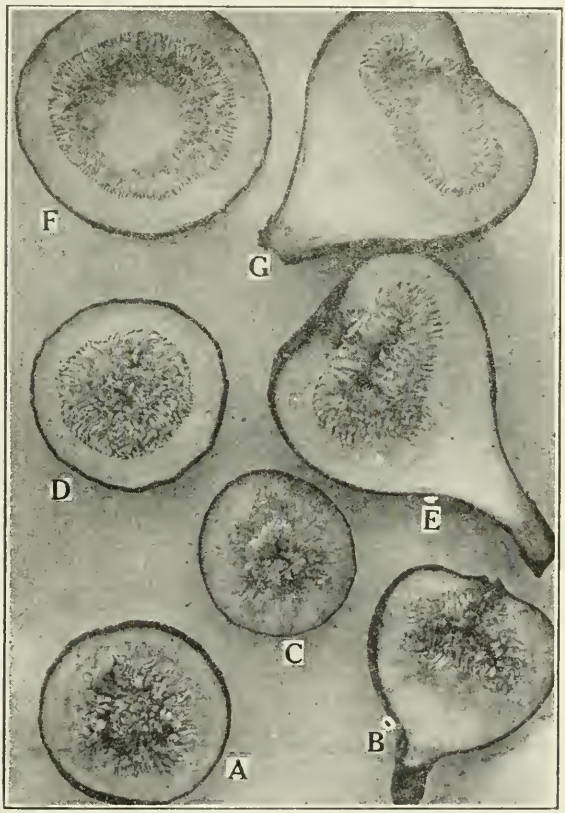

Fig. 5.—*A*, *G* and *C*, sections of fruit of Capri No. 1. *G*, fruit split lengthwise, showing the large number of plump gall flowers lining the bottom and sides of the cavity. Above, the staminate flowers surround the "eye," through this opening the fig wasp (*Blastophaga psenes*) makes its escape on emerging from the ovaries of the gall flowers in which the insect passes its life cycle. *A*, upper portion of fruit, showing a few gall flowers with the staminate ones grouped in the center. *C*, interior view of the apex, showing grouping of staminate flowers through which the *Blastophaga* must force its way in order to escape from the syconium.

D and *E* are cross and longitudinal sections of the fruit of a Smyrna variety, showing the large, plump, and rather coarse pistillate flowers lining the entire cavity of the syconium.

F and *G* are sections of an Adriatic type of fig, showing character of the chaff-like male flowers.

Observations on Capri figs show no yield of insect-bearing figs from varieties other then Capri No. 1. It is apparent, however, that this Capri produces figs the year through, since *Blastophaga*

has been present during the past three successive seasons. The yield of the winter crop is sufficient to reestablish the colonies of wasps in the Capri figs and to provide for caprification of edible forms.

RESULTS OF THE SURVEY AND INVESTIGATION

Observations have convinced us that fig growing has passed the experimental stage. The survey has also shown that there are no extensive plantings. The home orchard usually consists of from one to several trees with an average not to exceed 15 or 20 for each farm on which trees of bearing age occur. An estimate of 6,000 trees bearing satisfactory yields of fruit would be a liberal one. All types of edible figs comprising the 600 or more horticultural forms occur among these plantings, these forms and varieties being widely disseminated throughout the warmer portions of the State. It is evident that many varieties find the soil and climate congenial, producing a satisfactory growth of foliage and yielding fair crops of fruit. This is also evidence that some varieties have been grown for many years and have produced good yields of fruit annually.

An inspection of the fruit from various parts of the State has convinced the writer that there are many desirable varieties quite generally distributed. Certain varieties show a great range of adaptability, while the individuals of these varieties show much greater variation. Furthermore, definite proof has been secured showing that far greater yields would be realized if the operator understood the nature of the plant and the method of handling it. Inquiries concerning increased plantings emphasized the fact that general information concerning the true value of the fruit for food, the large range of uses to which it might be placed, and the method of propagating the plant, would not only be appreciated but would be of great assistance in the development of the new home orchard. The survey has shown that the fig grower should have such information and explanations with reference to the nature of the types and varieties, as well as general instructions for planting, tilling, irrigating, and pollinating. It is generally conceded by the orchardist that fig growing is profitable, the entire crop being utilized as fresh, canned, or bottled fruit.

THE FIG PLANT

Originally the fig was represented by a single species known botanically as *Ficus carica*. It is from this species that all common edible forms have been developed. The forms producing edible fruit

now number several hundred. The varieties of this group, while semitropical in nature, are all deciduous, yet they usually carry a small crop of fruit through the winter on their naked branches.

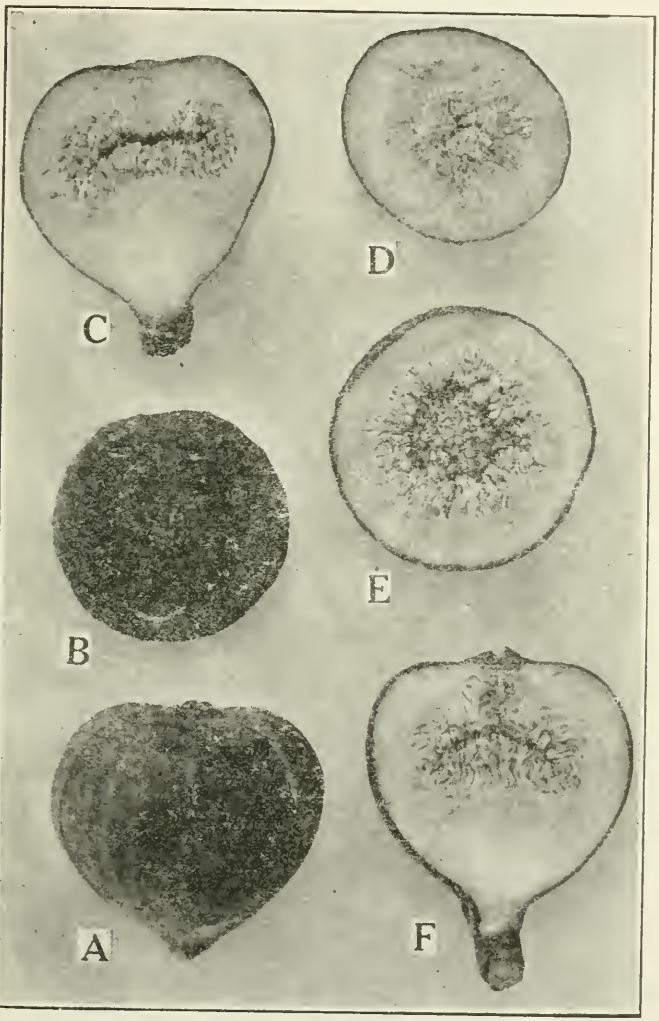

Fig. 6.—Side, apical, longitudinal, and cross section views of Capri figs. *A* and *B* are excellent views of the "eye"; *F* and *C* illustrate the structure while *E* and *D* show the location and relative proportion of staminate to gall flowers. From a photograph by W H Lawrence.

Groups of figs.—Among the cultivated forms we now recognize five distinct groups which for convenience may best be arranged under both common and botanical names. These groups are:

(1) Capri (*Ficus carica* var. *silvestris*).
(2) Smyrna (*Ficus carica* var. *smyrnica*).
(3) San Pedro (*Ficus carica* var. *intermedia*).
(4) Common or Adriatic (*Ficus carica* var. *hortensis*).
(5) Cordelia (*Ficus carica* var. *relicta*).

The fruit of the fig.—While these groups vary greatly in habits and character they do agree closely with respect to the general nature and appearance of the fruit. The fruit of the fig consists of a fleshy receptacle called a syconus. This body is the deeply concave axis of the inflorescence on the inner surface of which the flowers and subsequently the fruit is borne, the entire body becoming edible at maturity. The cavity is closed by small bracts. It is the detailed information concerning the fruit and crops that the grower most needs to guide him in handling the fig intelligently.

Kinds of flowers.—There are four kinds of flowers produced by the fig: (1) staminate, (2) pistillate, (3) mule, and (4) gall. All the flowers are borne on the inner wall of the fleshy receptacle or syconus, commonly called the fruit. The fruit is a succulent, hollow stem with an eye at the apical end, hollow in the center with the wall lined with a thick coat of flowers. The five varieties of figs are grouped according to the kind of flowers borne in the receptacle.

(1) Staminate flowers, erroneously called male flowers, are rarely found except in the Capri fig. They may also occasionally appear in Smyrna figs. The flowers are minute and rather inconspicuous, consisting largely of four anthers borne on short filaments.

(2) Pistillate flowers, erroneously called female flowers, are common in the edible figs but may also occur in small numbers in the Capri fig. The pistillate flowers are small and consist largely of the ovary, style and stigma, the essential organ being the most conspicuous.

(3) Mule flowers are rudimentary or degenerate pistillate flowers that do not require pollination to induce edible maturity of the fruit. This case may be termed horticultural maturity, since botanical maturity would involve the production of viable seeds. Mule flowers are common and characteristic of Adriatic or common figs. They may be associated with pistillate flowers which not infrequently occur in this group.

(4) Gall flowers are probably degenerate pistillate flowers which have become modified through long use by *Blastophaga psenes*, the fig wasp, as a place in which to pass its life cycle. These flowers are found with rare exceptions only in the syconus of the Capri fig.

CROPS OF FRUIT

The fig is usually a profuse bearer, producing one to three crops of fruit each year. Since the staminate and pistillate groups vary greatly, separate discussions are introduced.

The *Capri fig* naturally produces three crops each year, none of which are edible. These crops are known as the winter or mamme, spring or profichi, and summer or mammoni. Certain forms of Capri figs produce one, two, and three crops, the number varying with the species. The presence of well developed but dormant fruit on the naked branches throughout the winter is essential to the propagation of *Blastophaga psenes*, the fig wasp, the life history, habits, and use of which insect are discussed later in this paper.

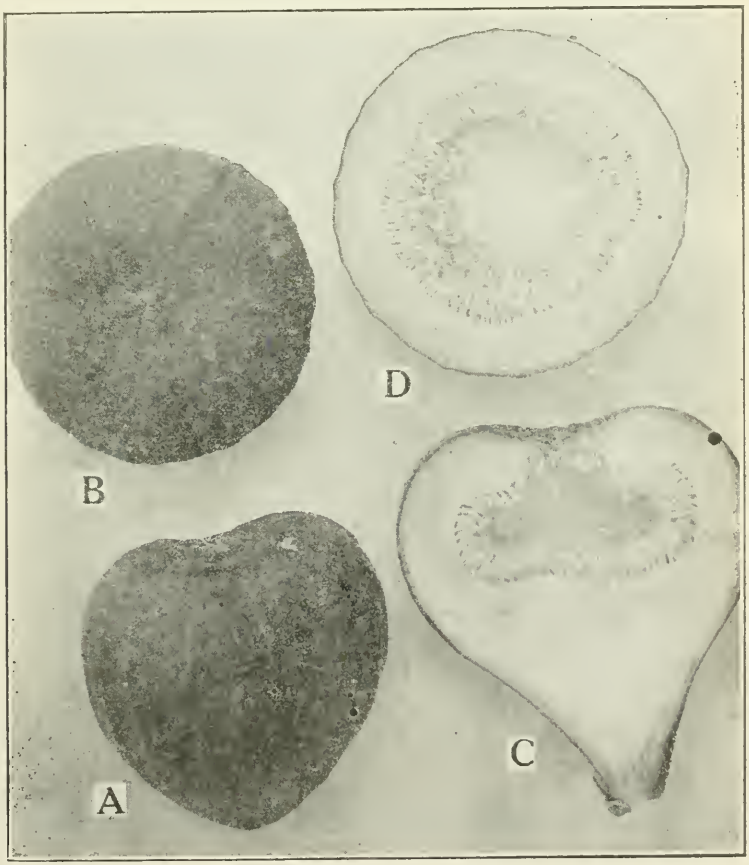

Fig. 7.—Adriatic type of fig. *A*, side view; *B*, apical view; *C*, view of the fruit cut into section lengthwise, showing the cavity lined with flowers, with eye leading to the outside; *D*, cross section of the fruit through the larger portion of the cavity. Photograph by W. H. Lawrence.

The *edible fig*, which includes all forms of figs producing edible fruit, sometimes produces three crops. In this group there is no sharp distinction, in many cases at least, to be drawn between the second and third crops. The first crop, or Brebas, is easily distinguished by its position on the old wood and the date of maturity. It may be said, however, that this crop is composed of the late maturing forms of autumn that have passed the winter in the green stage, ripening in early spring. There are two distinct crops in the San Pedro group, the first characterized by mule flowers, while the second bears pistillate flowers.

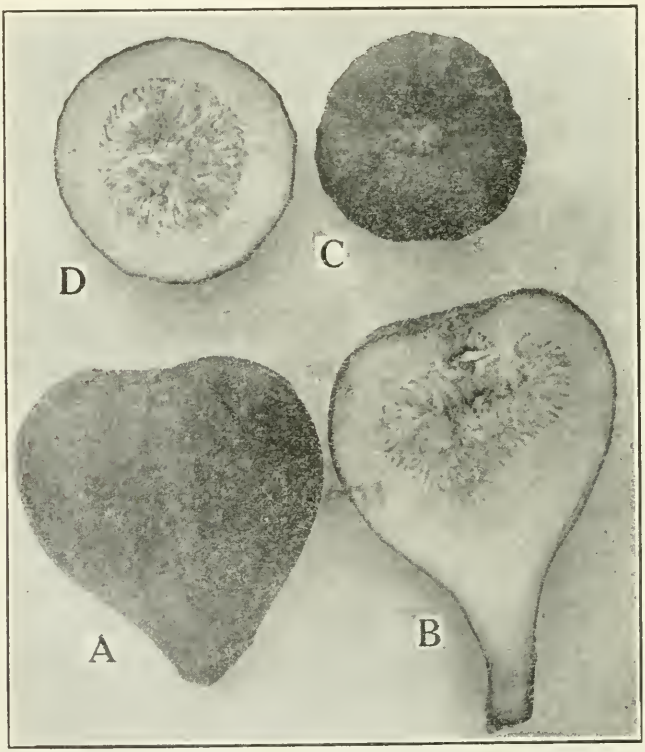

Fig 8.—External views and interior longitudinal and cross section views of the Smyrna fig, showing the relatively small cavity well filled with a dense lining of large, plump, and coarse pistillate flowers. From a photograph by W. H. Lawrence.

Classification of figs.—Two main divisions might be made of the five varieties: (I) pollen producing forms and (II) nonpollen producing forms.

(I) The pollen producing forms would include the Capri and Cordelia figs. This group may be further subdivided by noting

that the Capri figs bear gall and staminate, while the Cordelia figs is characterized by the presence of pistillate and staminate flowers.

(II) The nonpollen producing forms include three varieties—the Smyrna, San Pedro, and Adriatic. The further subdivisions of these groups permit the following arrangement:

Smyrna—producing mainly pistillate flowers, all crops.

San Pedro—producing both mule (first crop) and pistillate (second crop) flowers.

Adriatic—producing mainly mule flowers, all crops.

New type of fig.—A new type of fig grown from seed is described by Swingle* as " . . . a sort of hermaphrodite tree that had enough of the qualities of a Capri fig to support the *Blastophaga* and enough of those of the fertile tree to produce an abundant crop of summer generative buds just as the spring generation Capri figs were ripening. It also bears numerous fertile seeds mingled with insect-bearing galls. By planting this variety among other Capri figs the *Blastophaga* will be able to breed uninterruptedly throughout the year and not, as is now the case, almost completely die out in midsummer."

Characteristics of varieties.—There are five varieties of *Ficus carica*, as explained on an earlier page.

The *Capri fig* (*Ficus carica* var. *silvestris*) is a wild fig that has been brought under cultivation. There are about thirty forms grown in California and the Southwest. The fruit produced by this group can not be considered edible. One, two, or three crops of fruit are produced each year.

There are two forms of Capri figs, the pistillate and the staminate. Ths pistillate form is very rare and needs only brief mention. It is perhaps the parent form of the Smyrna group. The staminate form is the more important since it is the host for the fig wasp and produces the pollen for use in the caprification of pistillate figs.

The three crops produced by the Capri figs show marked differences in structure. These crops are known as the mamme, profichi, and mammoni. The mamme, or first crop, forms in the fall and matures in early summer about the same time that the brebas, or first crop of edible figs, ripens. In this crop the syconus is only provided with gall flowers, possibly a few pistillate ones, yet no seeds are matured; the staminate flowers are absent or very rare. hence no pollen is produced by this crop. The sole office of the crop, therefore, is to carry the fig wasp through the winter. The crop matures on the wood of the previous season.

*The Fig in California Separate, California State Commission of Horticulture, p. 3.

The profichi, or second crop, ripens before the second crop of edible figs. It appears in May, or earlier, and matures in June or July. This crop matures large numbers of gall and staminate flowers, no pistillate flowers occurring. It is from this crop that pollen is carried to the Smyrna and second-crop San Pedro. An examination of a syconus shows the gall flowers arranged in the lower portion of the receptacle, while the staminate are grouped around the eye at the apical end.

Fig. 9.—Group of Black Smyrna figs that have reached edible maturity. Note the large and open "eye," which makes it possible for insects, fungi, bacteria, and water to enter the fruit before and during the ripening period, causing the fruit to sour. From photograph, horticultural files, Arizona Agricultural Experiment Station.

The mammoni, or third crop, appears before the last of the profichi has disappeared. This crop contains a few each of staminate and pistillate, but a large number of gall flowers. This crop may occasionally produce a few seeds. Pollination takes place by the fig wasp carrying the pollen from the profichi to the mammoni syconia at the time the wasp leaves the crop of profichi, which has matured and is failing, to enter the mammoni crop. The primary use of this crop is to furnish a home for the fig wasp until the mamme form permits the establishment of the fig wasp in winter quarters. Mammoni figs are produced on the wood of the present season.

The *Cordelia* and allied forms (*Ficus carica* var. *relicta*) differ from the true Capri in producing both pistillate and staminate flowers. The arrangement and position of both sexes of flowers correspond to that of the Capri fig. The fruit of this form remains dry and inedible in the zone occupied by the staminate flowers, while below, the pistillate flowers, that produce seeds, develop into perfect edible maturity. This form represents the true Capri fig in the presence of staminate flowers, and the Smyrna by the occurrence of pistillate flowers capable of fertilization and the production of seeds.

Perhaps the best known of this group are the Bellona, Drap d'Or, Corsica, and Cordelia.

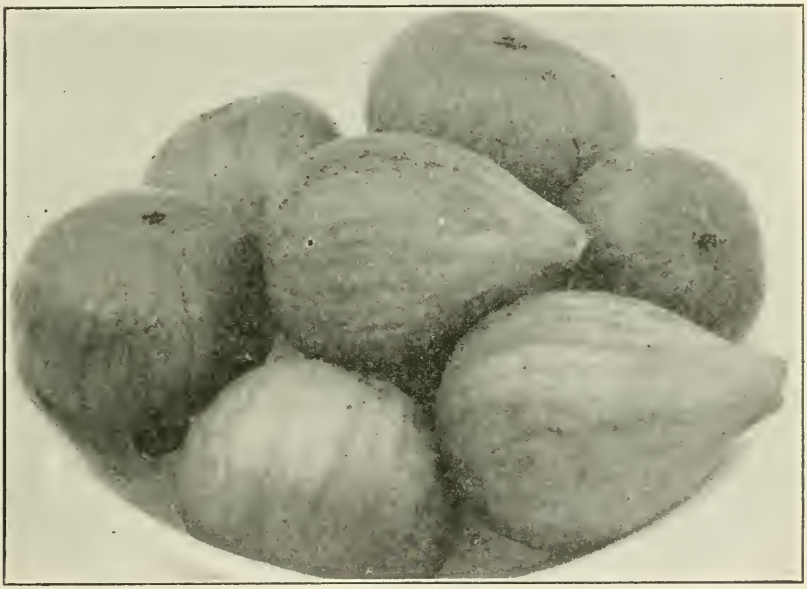

Fig. 10.—A group of well matured White Adriatic figs. Note character of the "eye." From photograph, horticultural files, Arizona Agricultural Experiment Station.

The *Bellona* and *Drap d'Or* were studied by the writer at a time when the supply of fruit was limited. The three available specimens of Bellona all presented an abundance of flowers with the pistillate grouped in the basal portion, and the staminate occupying the apical portion. Of four specimens of Drap d'Or, three presented the same structure as described for Bellona, while the fourth did not contain staminate flowers. Both these varieties are characterized by the basal portion of the syconia reaching edible maturity, while the upper portions remain dry, leathery, and develop little or no flavor.

The *San Pedro* group (*Ficus carica* var. *intermedia*) produces two main crops of edible figs. The first crop contains mule flowers that are not susceptible to fertilization, hence pollination is of no value to the horticultural maturity of the fruit. The second crop, however, contains pistillate flowers only, and in the absence of pollen the syconia drop before reaching edible maturity, which is only induced through fertilization and botanical maturity of the pistils. This group is intermediate between the Smyrna on the one hand and the Adriatic on the other. Yellow, White, and Black San Pedro, Gentile, Pitontoni, and Portuguese are perhaps the best known forms of this group.

The *Adriatic or common fig* (*Ficus carica* var. *hortensis*). To this group belong the common figs grown so extensively throughout the Southern States. The syconia contain large numbers of mule flowers and occasionally a few pistillate ones susceptible of fertilization. Pollination is not necessary, however, to the production of fruit, since horticultural maturity is perfect in this case. This fig is perhaps a form in which rudimentary pistillate flowers occur not susceptible to pollination, having lost their character of reproduction by seed, yet maturing the fruit horticulturally.

The *Smyrna fig* group (*Ficus carica* var. *smyrnica*). This group undoubtedly originated from the pistillate Capri fig. The syconia bear true pistillate flowers and these require pollination to induce edible maturity. It is this very large and important group and the lesser important San Pedro group that require the growing of the staminate Capri fig to furnish the pollen necessary to the setting and maturity of the fruit.

FIG CULTURE

CLIMATIC REQUIREMENTS

The fig is subtropical. A summer temperature of 90° F. to 110° F. in the shade, from July to October, accompanied by a comparatively dry atmosphere and no rain, is quite ideal. Cold nights in summer, or rainy weather during the ripening period are very objectionable and destructive, causing much of the ripening fruit to sour before reaching edible maturity. Winter temperatures of 12° F. to 14° F. for short durations are not apt to do serious damage, yet these temperatures may be dangerous when the trees are not given winter protection.

SOIL

The fig grows well on all types of soil. A well drained, moist but mellow, sandy loam, well filled with humus is most desirable.

While the fig is not exacting, it is notable that a very light sandy soil with a low water-holding capacity is not as desirable as a heavier and more compact one in which a larger proportion of moisture is present during the earlier portion of the growing season. Sandy soils are especially undesirable where nematodes are abundant. Ozonium-infested soil is likewise objectionable since this fungus may attack and destroy or badly weaken the trees.

Fig. 11.—Group of well matured figs of the Black Mission variety. Note character of the "eye." From photograph, horticultural files, Arizona Experiment Station.

Alkali soils are not profitable for fig production. According to Hilgard, healthy fig plants have been observed on soil containing as much as 6,600 pounds per acre-foot, of mixed alkali sulphates, and 200 to 300 pounds, of carbonates and chlorides. However, much larger amounts of alkali salts have been found in soils occupied by figs which did not show any injurious effects on vegetative growth. For productive returns, however, it is perhaps advisable to avoid soils carrying more than the minimum amount the plant endures without visible signs of injury.

SELECTING VARIETIES

A study of those varieties of figs grown in the Salt River Valley shows the most hardy and prolific varieties to be the Lob Injir,

Bulletin Smyrna, Black Mission, Black Adriatic, Bardajic, Rose Blanche, Dauphine, and Ronde Violette Hative. Other named varieties that can be recommended are the White Adriatic, White Mission, Angelique, Brown Turkey, Black and White San Pedro, Magnolia, and White Endich.

The selection of varieties that have proved themselves in a locality safeguards the grower in securing desirable trees.

PROPAGATION OF THE FIG

The fig is propagated from seeds, shoots, hardwood cuttings, and grafts, and may be budded or grafted.

Propagation by seeds is apt to be disappointing, since the seedlings do not come true to type. This method is only possible in those groups that produce viable seeds. The practice is to be condemned except when it is the purpose to originate new and more desirable sorts.

Reimer* in discussing the cause of premature dropping of figs, said: "At least 95 per cent of the figs examined were seedlings of the true Smyrna fig. Most of the seedlings bear fruit similar to that of the Capri fig; very rarely is it like that of the true Smyrna fig. . . . These seedling figs as a rule are absolutely useless as far as the fruit is concerned."

According to Swingle,† of the 139 seedling trees in the Maslin orchard in bearing in 1908, 74 were Capri figs and 65 Smyrna. Of the former, 20 or more are valuable for planting in the Capri orchard; of the latter, 1 in 10 was worthy of a trial with a view to its introduction as a commercial sort. He states further, however, "at least two and possibly more of them show a very valuable characteristic not known in any fig of the Smyrna type now cultivated—the fruits becomes sealed automatically as they ripen." Self-sealing is due to a pellucid gum filling and then hardening in the eye, preventing entrance of moisture, bacteria, fungi, and insects.

Selecting stock for propagation.—The safest and surest way to secure trees adapted to local conditions in the State is to grow them from hardwood cuttings. Elsewhere in this paper mention is made of both named and unknown forms that are adapted to local conditions.

Reference is sometimes made to orchards that came into full bearing and produced good yields but have since disappeared. The Thirteenth Census of the United States shows a decrease in bearing

*Cause of Premature Dropping. Bull. 208, N. C. Exp. Sta., p. 204.

†The Maslin Seedling Fig Orchard at Loomis, California, and its bearing on the Smyrna Fig Industry of the Country. Separate, California State Commission of Horticulture, p. 3.

trees and yield of fruit during the preceding ten years. This decrease was no doubt due to an inadequate or intermittent supply of irrigating water, the destruction of varieties by low temperatures occurring at rare intervals, and the discarding of undesirable forms which sour upon the trees before ripening, or which lack flavor and quality, and varieties which are too soft for shipping. The decrease in number of trees has been most fortunate as far as the selection of stock for propagating purposes is concerned, since undesirable forms have largely disappeared.

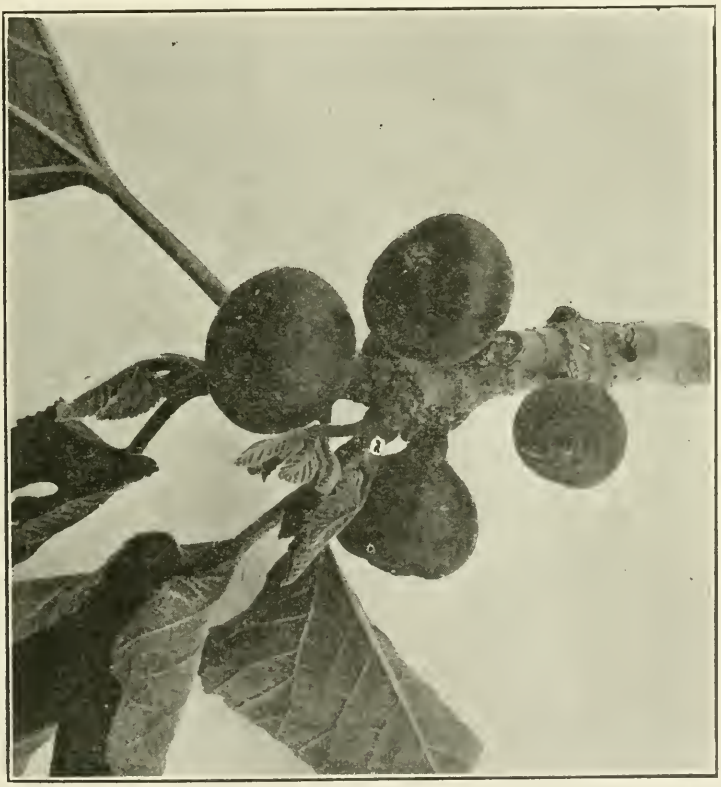

Fig. 12.—Terminal branch from Capri No. 1, showing four Capri figs making normal growth due to parasitism by *Blastophaga psenes*, the fig wasp. From photograph, horticultural files, Arizona Experiment Station.

The representatives of Adriatic types growing in nearly every portion of the State where winter temperatures rarely fall below 15° F. to 18° F., except for periods of short duration, and the surviving specimens of earlier introduction from Old Mexico, California, and other fig producing sections, give a large assortment of varieties

and an immense supply of propagating stock adapted to the immediate local conditions. Even then careful selection of the individuals of a variety should be made. This is essential to the securing of a form that will produce fruit of good quality, and a good yield, and which will give a regular annual production. Perhaps even as great care should be paid to the selection of forms that will endure extremes of weather. This is particularly true in the selection of Smyrna varieties. In the Salt River Valley, where the Capri fig is being grown, the influence of temperature on the production of Capri figs is very noticeable, since there is but a single form that carries mamme through the winter.

Vegetative propagation by the use of mature wood cuttings is the most practical method, especially where the work is done upon the farm. Mature or hardwood cuttings should be made in winter, when the least sap is flowing, using well ripened wood free from winter injury. The length of the cuttings depends upon the size and age of the wood. They range from 1 to 14 inches in length, the average being 4 to 6 inches. In the preparation of the cuttings the wood should be sectioned exactly at the node, so that no visible pith will show at either end. Planting may be done at once with two eyes exposed, or the cuttings may be heeled-in in soil well tamped to exclude the air and prevent drying. Planting may be done in late winter or early spring; it may be done directly in the field or in the nursery where the stock is grown for a season before being set in the orchard. One should avoid wet soils, since the roots make a very succulent growth and are extremely susceptible to injury at the time of transplanting. The soil should, however, be moist. In the case of too rapid rooting the cuttings may be dried slightly before planting. Desiccated cuttings should be revived by soaking them in water for a short time. After planting avoid covering.

Propagation by shoots is easily accomplished. The suckers arising on the roots and lower portion of the trunk will soon take root and may then be removed with a small portion of the parent tree and set in the field.

Unproductive and undesirable varieties of vigorous growing capacity may be grafted or budded. Grafting usually gives the best results and may be done conveniently by cutting off the stem, notching the side, then cutting a V-shaped slit about 1¼ inches long into which a scion of two buds is inserted, tied, and waxed. Two-year old wood is used for grafting.

ARRANGEMENT OF VARIETIES IN THE ORCHARD

Varieties may be arranged to suit the fancy of the grower. In the selection, care must be taken to secure the right varieties and forms.

Edible figs.—An orchard of edible figs may include any or all forms. Should the area include forms requiring pollination as well as those not requiring pollination, it is desirable to group together the pistillate forms in order to facilitate orchard caprification. When either Smyrna or San Pedro figs are grown it becomes necessary to include Capri figs in the planting.

Capri orchard.—There are about 30 varieties of Capri figs which differ greatly in bearing habits, producing from one to three crops each year. The selection must include varieties that will produce a continuous crop of figs the year through. The loss of a crop of the series at any time means a loss of the fig wasp. Since the insect requires shade and a cool place, best results are secured by growing the Capri trees rather closely together and in a more or less protected and shaded place. Furthermore, in the care of the tree during the year one should avoid pruning, since this group of varieties will give the best results when the tops are dense. The Capri orchard should be placed within easy access of the edible fig-bearing orchard.

While Capri figs grown in the Salt River Valley produce crops in summer they do not carry a crop through the winter with the exception of Roeding No. 1, which usually carries a sufficient number of mamme to reinfect the spring crop of Capri figs.

Assortment of Capri trees.—Capri figs are a class by themselves. The sole purpose of this variety is to provide a home for the fig wasp. Some varieties produce three continuous crops each year, while others produce only one or two. Capri trees do not produce a succession of crops until they are four years old. The collection of Capri figs should then include as many varieties as will supply a continuous crop of figs to carry the wasp through season after season and year after year.

Capri No. 1 seems to be the ideal form. The remaining varieties, however, do produce good crops and will, when pains are taken to caprify them, produce a large number of wasp-bearing figs. With Capri No.1, bearing practically the year through, the ideal combination would be this form grown with *Ficus pseudocaypa*. The overwintering crop of the latter species is provided with stamens and will pollinate the first crop of Smyrna. It seems to be more hardy than other Capri figs and bears mamme and profichi crops.

The proportion of Capri trees.—The general practice is to grow

two Capri trees for each acre of Smyrna or San Pedro, yet the writer recommends twice this number for use in the Salt River Valley. The number of trees must be varied since the size of the fruit varies greatly, in some instances each specimen producing only 500 while the larger forms may produce 2,000 or more wasps. The profichi crop is the one that concerns the orchardist.

Providing winter protection.—The problem of providing winter protection consists in the growing of one or more varieties of Capri trees in a more or less protected place. The growing of the Capri tree in the bush form, making it possible to cover the plant during severe winter weather and when spring frosts occur, would undoubtedly make it possible to carry a larger number of Capri figs through a winter destructive to the mamme crop. The Capri varieties are apparently less hardy than many of the edible fruit-producing ones, since the fruit is very easily destroyed by freezes and frosts. The problem of carrying the *Blastophaga* through the winter is a problem so important that an attempt should be made to protect the Capri trees in order that they may carry the fruit through the winter months.

Even in the most favorable localities, conditions at times may occur that will kill the mamme crop, thereby destroying the fig wasps. Experimental work done in collecting Capri figs late in the season, packing them in damp mud and damp sphagnum in fruit jars and similar vessels and storing them in outbuildings, shows that the fruit will pass the winter in good condition and the wasps will emerge in April from figs gathered late in December.*

PLANTING AND CARE OF THE YOUNG ORCHARD

The fig plant has a spreading habit and is a surface feeder. The average distance for planting is 28 by 28 to 30 by 30 feet. On sandy soils where top growth is limited, 25 by 25 feet is good space, yet when they grow large,35 by 35 feet gives the trees none too much room after they come into full bearing.

Great care is required in transplanting the fig. At the time the trees are dug from the nursery row the roots must not be exposed to the sun or dry air, since slight exposure will injure and possibly kill them. While planting, the same precautions must be taken. Puddling the roots is the best method of handling previous to the removal of mutilated and discolored branches at the time of setting. When planting is done, the soil must be moist or a sufficient quantity of water applied to settle the soil around the roots. The moist or

*Rixford, G. P. Requirements and Possibilities of Fig Culture in California. Preserving Mamme Capri figs. Reprint, Monthly Bulletin California State Commission of Horticulture. Feb. 1915, Vol IV, No. 2, p. 5.

wet soil should be covered with a mulch of dry soil about 4 inches deep.

Usually a single tree is set in a place, yet under conditions where low bush forms are desirable for ease in covering during the winter, three to five plants are set in a group. The stems should be protected from sunscald.

After setting, the group needs little or no attention. The single plant should be headed not to exceed 24 inches, except when frost is apt to occur, killing the stems, under which condition very low heading is practiced to induce the formation of several standards. Subsequent pruning for three or four years should be done to form the framework. Young trees come into bearing very early and special attempts should be made to have the tree properly prepared. After fruiting begins the pruning should be done merely to remove weak or dead wood and to shape the top advantageously for the gathering of the fruit. The first year after setting, this method of pruning consists in saving three to four scaffold branches, shortening them not to exceed 12 inches in length, and so arranging them as to grow a vase-shaped top. The following season two branches, each cut back about two-thirds its length, are left on each scaffold, with the removal of all drooping ones. The third season the growth is shortened about one-third, and thereafter the top is merely thinned to provide good space for the bearing wood.

On the fig all the fruit is borne on one-year-old wood. In training it is well to bear this in mind and to avoid the removal of too large a proportion of the bearing surface of the plant.

THE PRUNING OF BEARING TREES

Due to the small size of second-crop figs an attempt was made to influence the development of the fruit and growth of new wood on Lob Injir, Black Smyrna, and Black Adriatic. Practically one-half of the bearing wood was removed in each specimen pruned on February 3, 1914. Heavy pruning done to thin the fruit apparently has a tendency to reduce the yield and shorten the picking season and does not influence the size of the fruit, yet replaces the old with a larger proportion of bearing fruit.

CULTIVATION AND IRRIGATION

Fig trees are shallow rooted but gross feeders. Clean cultivation is perhaps the best method of caring for young trees. They should at least be given good care until they become well established. Injury to the top, or adverse climatic or soil conditions while the tree is young and especially before the root system is established,

usually dwarfs the tree permanently. It is therefore advisable to apply water sparingly, yet abundantly enough during the early development of the plant to induce deep rooting. Since many of the feeding roots occur near the surface, shallow tillage is essential. Mulching the ground is known to be very beneficial. Application of barnyard manure when top growth is not satisfactory induces the development of new wood. Commercial fertilizers carrying potash, phosphoric acid, and lime are generally recognized as valuable on old and more or less depleted soils.

WINTER PROTECTION FOR FIG TREES

No attempt is made to protect the trees from injurious temperatures except in those sections where the fig plant will not endure exposure until two or three years of age. In most places where protection would carry the tree through the winter, the cost of necessary attention is so slight that one could afford to prepare the trees for cold snaps by wrapping the stems in straw, old stalks, or other materials, or by covering with straw and dirt so that the trees, when of a bush form, may be bent over and covered conveniently.

CAPRIFICATION

Pollination of the fig is commonly termed "caprification." This is an important practice and requires detailed instruction, since only accurate work will give satisfactory results. It becomes necessary at this point to consider methods of caprification.

The operator of the Smyrna and San Pedro fig orchards must thoroughly understand the habits and life history of the fig wasp, since this insect is the sole means by which pollen can be conveyed from the staminate to the pistillate flowers. This insect is a parasite in the fruit of the Capri fig and can not live under other conditions or in other kinds of fruit. This wasp is found native only in sections where fig growing has been practiced for centuries or where the Capri fig is native. It must therefore be introduced where needed to insure pollination of the fig. These conditions make it mandatory to propagate the wasp.

The development of three crops on the Capri fig each year makes it necessary for the insect to change quarters the same number of times each growing season. Unless the crops are available to provide suitable quarters the wasp will perish, notwithstanding the fact that climate and other conditions may be ideal.

Plants requiring caprification.—Attention has previously been called to the necessity of the caprification (pollination) of Smyrna and second-crop San Pedro figs. Frequently the orchardist overlooks

the fact that the Capri fig must also be caprified, since some forms of Capri figs do not produce continuous crops. There is also almost a break between the profichi and mammoni, since nearly all the insects escape from the former crop before the earliest fruits of the latter crop are old enough to accommodate the fig wasp. This is a wise provision, considered from a natural point of view, and is also very important commercially. While the profichi crop is useful in the caprification of edible figs, the mamme and profichi crop are used in the caprification of Capri figs, and especially in perpetuating the fig wasp.

Methods of caprification.—To intelligently caprify an orchard the operator must become familiar with the general appearance of the Capri fig when the wasp has developed to the stage of emergence. By opening and examining a few, one soon is able to determine the date the fruit is mature for caprification, by the external appearance, especially the color, of the fig.

Mature figs are either hand picked or when out of reach are knocked from the trees with light bamboo poles. Picking is done in pails and begins at daylight while the figs are cool, since the wasps begin flight as soon as the fruit warms up. Emergence continues with interruptions for several hours each day for about ten days.

Distribution of the crop is done usually by means of cone-shaped baskets about 3 inches wide at the opening and 10 inches long. Six to fifteen specimens of average size are required for trees 4 to 6 years old, while 20 to 100 are needed to caprify trees 10 to 40 years old. For small trees one basket is used, while in large ones two or three hung in different locations in the top of the tree may be necessary. Caprification is done 7 to 10 days apart and should continue until the entire crop is pollinated.

How caprification is accomplished.—During June, Smyrna figs mature to the size of marbles, the flowers presenting a waxy appearance. At this stage of maturity pollination will take place. The profichi crop of Capri figs should now also be mature with the fig wasp ready to emerge. Attention has been directed to the fact that the profichi crop contains both gall and staminate flowers. With the gall flowers in the lower end of the cavity, and the staminate above, forming a dense mass of flowers full of loose pollen surrounding and covering the eye—the only means of exit—the female wasp in forcing her way through the stamens becomes well coated with the pollen, which, however, she unsuccessfully attempts to remove on reaching the opening and before flight. On entering the pistillate syconia the pollen is scattered thoroughly over the

pistils while the female works vigorously searching for a place to deposit her eggs. The caprification of a crop maturing through a month or more is possible, since the syconia of the profichi crop mature in the same manner with insects emerging from the crop for about 30 days, with further distribution of a crop of wasps emerging from the individual syconia for a period of about 10 days.

Life history of the wasp.—As has previously been suggested, there are three generations of the fig wasp each year. All stages of transformation from the egg to the adult take place within the ovary of the gall flowers. Both sexes of the insect develop under the same conditions, a single individual occupying an ovary. When they are ready to emerge the males appear first. They are wingless, smaller than the females, light brown, and are provided with strong jaws, useful in liberating themselves and the females

Fig. 13.—Smyrna figs that have been split open before reaching edible maturity. From photograph, horticultural files, Arizona Experiment Station.

from their quarters. On emerging, the males seek out the females and impregnate them, after cutting a small opening in the wall of the ovary enclosing them. The female, otherwise unable to escape, is strong enough to enlarge the opening in the wall of the fig ovary, made by the male, and makes her escape. The female immediately leaves the fig in which she has developed, in search of a suitable place to deposit her eggs. The males never leave the syconia in which they mature. Fortunately for the fig grower, the female wasp does not have the ability to discriminate between Capri pistillate and other buds of the fig, but enters any and all in search of a place to deposit eggs, vigorously working among the flowers.

Emergence of Blastophaga.—The dates of emergence of the *Blastophaga* (fig wasp) vary with the locality and seasons. There is but

slight variation in the Salt River Valley during successive years. The following dates are approximate and are those recorded for 1915. The *Blastophaga* began to emerge June 1 and were approximately all out by June 15. The mammoni crop was well formed by August 5, having matured enough to provide quarters for a few of the fig wasps. The emergence of the three generations of the wasp during a period of several days, and the overlapping of the three crops of Capri figs, make it possible for the wasps to find quarters for each generation.

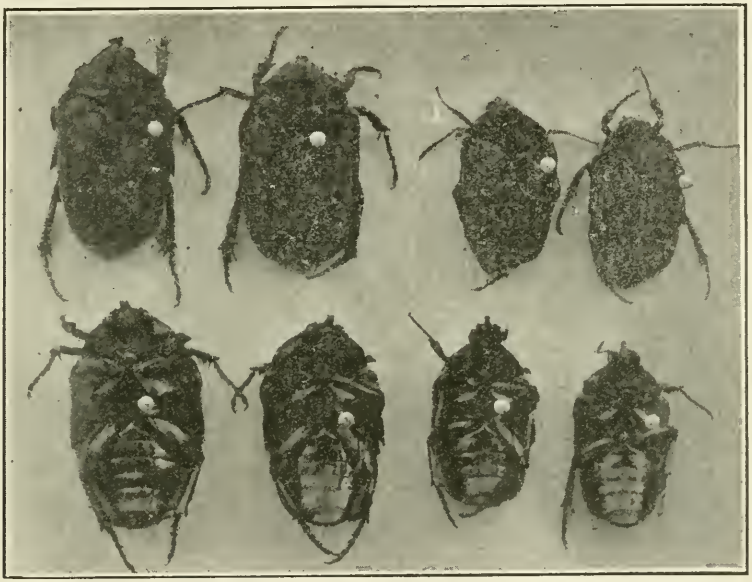

Fig. 14.—Dorsal and ventral views of the "June Bug." Natural size, from photograph horticultural files, Arizona Experiment Station.

SPLITTING AND SOURING OF THE FRUIT

Cold weather and rains cause all or a portion of the fruit of some forms to sour upon the tree just previous to picking time. Attention has been called earlier in this publication to self-sealing forms that are not susceptible to injury by rain, since, on approaching edible maturity, a pellucid gum is deposited in the eye, sealing it against the entrance of bacteria and fungi and against invasion by insects. Cracking, splitting, and souring of the fruit may occur in the same specimen under certain conditions.

During the 1915 season, a large percentage of the Black Smyrna and White Adriatic cracked and soured while ripening. The estimated yield from the former (two trees) was 300 pounds,

with 36.5 pounds edible, and the latter (two trees) 400 pounds with 86 pounds edible. In this instance the White Adriatic did not mature its fruit properly since during the ripening period hardly two figs showed the same flavor or firmness of flesh.

Both the Royal Vineyard and Lob Injir produced split fruit during 1915. Splitting is undoubtedly due to increased growth of the fruit following a period in which the tissues grew slowly or ceased growth and became more or less woody, under which condition rupturing takes place to accommodate the growing portions. The solution of the problem lies in properly tilling and irrigating the orchard to induce a uniform growth of tree and development of fruit, or the use of nonsplitting and self-sealing forms in localities adapted to their growth.

PESTS

The June Bug is the one serious pest. In 1914 the damage done was somewhat later but more serious than in the following season. In 1915 they made their first appearance July 20 and seriously damaged the ripening fruit of White Adriatic, Bulletin Smyrna, Lob Injir, and Black Adriatic.

Their method of feeding makes it impossible to combat this insect by spraying.

They may be collected quite rapidly by using a long, home-made tin tube with a wide flaring end; and a light but broad bat. When disturbed the insect usually drops some distance before taking flight. By holding the above mentioned tin tube below the beetle, then exciting it to flight and directing its course by use of the bat, it drops into the bell-like apex of the "bug catcher" and slides down the tube, where it is caught in a sack tied over the lower end. The beetles are then destroyed by pouring them into a pail of kerosene or crude oil.

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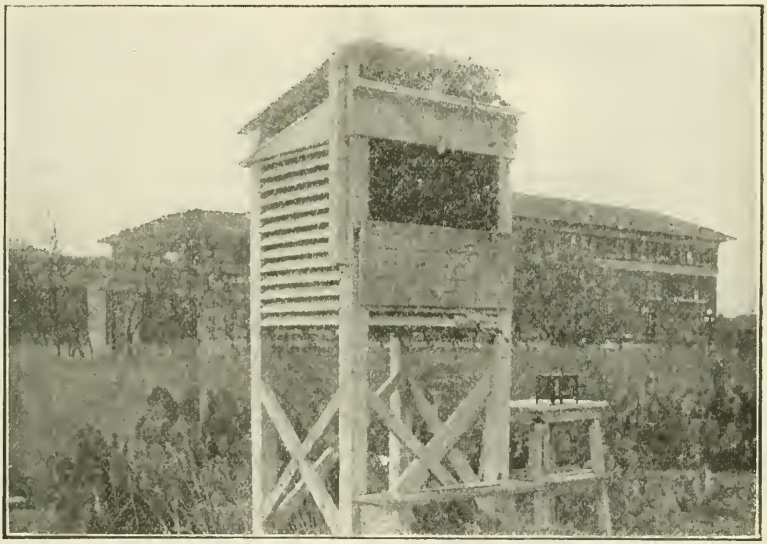
W. H. Lawrence.

University of Arizona

Agricultural Experiment Station

Bulletin No. 78



A Weather Bureau Shelter, with native forms of vegetation adapted to the region—cacti, desert grasses and *Parkinsonia* trees in the background.

Relation of Weather to Crops

AND

Varieties Adapted to Arizona Conditions

By Alfred J. McClatchie, J. Eliot Coit
and the Station Staff

Tucson, Arizona, October 20, 1916

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AGRICULTURAL EXPERIMENT STATION

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A diversified farming area in Southern Arizona. Alfalfa in the background with asparagus in the foreground. Sweet potatoes, tomatoes, castor beans, willows, cottonwoods, encalyptus, deciduous fruit trees and date palms are included in the view.

RELATION OF WEATHER TO CROPS AND VARIETIES ADAPTED TO ARIZONA CONDITIONS

Being a Revision of Bulletin No. 61, by Alfred J. McClatchie and J. Eliot Coit.

By the Staff of the Arizona Agricultural Experiment Station.

INTRODUCTION

In the following pages the aim is not only to record and discuss observations made during the past 18 years upon the relation of Arizona weather to crops, but to indicate as far as possible those varieties which by popular experience and Station tests have proved best adapted to the region. The large number of inquiries concerning crops adapted to different sections of the State indicates the need of keeping our printed information on this subject up to date. As new settlers are constantly coming into the country, and as the indications are that large numbers will continue to come in the future, a publication giving such general information will undoubtedly be useful.

This publication is a thorough revision of Bulletin 61, by J. Eliot Coit, which, in turn, was a revision of Part III of Bulletin 48, by Alfred J. McClatchie. The arrangement and much of the body of the publication are essentially the same, but considerable new matter has been added, and information concerning the various crops and their adaptability to different parts of the State has been revised in accordance with new developments and the added experience of the past several years. This information has been secured from records which have been accumulating at the Experiment Station farms, and from personal visits and correspondence of the different members of the Station Staff throughout the State.

The total agricultural products that Arizona will yield is limited principally by the quantity of water available. The area of arable land is far in excess of the acreage for which water can be supplied for irrigation. A large amount of this non-irrigable agricultural land lies in districts having enough rainfall to make dry farming practicable. In the most favored of these regions the rainfall is insuf-

ficient to utilize to its fullest value the natural soil fertility. In these regions, therefore, those methods of farming must be adopted and those crops selected which best conserve and most effectually use the limited water supply. The nature of these crops is determined largely by the climate of the region.

EFFECTS OF WEATHER ON DIFFERENT CROPS

METHOD OF KEEPING WEATHER RECORDS

For several years a record was kept at the Station Farm of the temperatures registered by maximum and minimum thermometers situated at various elevations from the ground. Besides the thermometers furnished by the Weather Bureau and kept in a regular instrument shelter, three sets of instruments of the same grade have been located on the south side of a post in the full sunshine, and daily records made from them. One set was located within a few inches of the soil, the second five feet above the ground, and the third was situated 10 feet above. For a year and a half three self-registering thermometers have been located underground upon a movable frame standing in a small shaft, one instrument being located five feet below the surface, one 10 feet below, and one 15 feet below. Records have been made from these instruments once a week.

Besides the above regular and continuous records, thermometers have been exposed among various growing crops, both above and under the ground, and records made therefrom. By these various methods an attempt has been made to ascertain and accurately register the actual temperatures to which crops have been exposed, both at various distances above the surface and at various depths underground.

The records kept from the instruments located in the government shelter and from the set located on the post at 5 feet from the ground furnish a comparison between the temperatures "in the shade" and those in the full sunlight. And as the instruments at the Phoenix Weather Bureau office only two miles distant are located 50 feet above the ground, the record reported from them furnishes data for quite a fair comparison between temperatures at that elevation and those under similar conditions 5 feet from the ground.

The work has also included keeping an evaporation record and carefully noting the effects of the weather on the various crops of the farm.

FACTORS INFLUENCING RESULTS

In considering the effects of the weather on different crops some difficulty is experienced in distinguishing with certainty between the results caused by the different phases of the weather and those caused by soil conditions. Differences in the physical and chemical conditions of the soil, especially differences in the amount of alkali, cause more or less marked differences in the success with which crops resist unfavorable weather conditions. These facts have been given due consideration and an attempt has been made to discriminate as accurately as practicable between those results due to differing soil conditions and those due to the effect of the weather.

In the study that has been made of the effects of the weather upon crops, five factors have been considered—temperature, direct sunshine, relative humidity, rainfall, and wind. Of these five the first has the greatest influence and the last the least influence. High temperatures limit crop production in southern Arizona considerably more than low temperatures. Relative humidity has a greater influence on crops than the local rainfall, the latter being too scanty most years to affect results very much. Most of the wind that occurs in the region affects vegetation principally by influencing the rate of evaporation of water from it, the velocity seldom being great enough to directly damage crops.

General Effects of Temperature

High and low temperatures affect crops in various ways, the principal ones being by preventing germination, by checking growth, by killing part or all of the vegetative parts, by injuring the blossoms, and by damaging the maturing product. The most pronounced effects are brought about in the first two ways and the least injury through the last. Crops affect considerably the temperatures about and among them. Through the cooling effects of evaporation and radiation combined, the temperature becomes lower among growing plants during cool nights than it is over bare ground, the difference varying from four to eight degrees. During the day also the rapid evaporation of moisture from vegetation causes the temperature to be a few degrees lower among plants than elsewhere. The temperatures to which crops are subjected are, therefore, more trying during frosty nights and less trying during

hot days than thermometers situated outside of their foilage would indicate.

The seed of most crops will germinate only during one or more definite portions of the year while the temperature remains within certain limits. For the seed of some crops this period is during the cool part of the year and for the seed of others it is during the warmer part of the year. Seeds of the former class either decay or remain dormant through the portion of the year during which the temperature is too high for germination and seeds of the latter behave similarly during the cooler portion of the year. The seed of a very few crops germinates here promptly during all parts of the year if supplied with water and of a few others the seed germinates during all of the year, except the hottest weather of summer and the coldest weather of winter.

Most crops make growth only during the portion of the year that the temperature remains within certain limits, maturing, dying, or becoming dormant when the temperature falls too low or rises too high. Most annuals grow continuously during a certain portion of the year and either die or mature when the weather becomes too cold or too warm, as the case may be. A few become dormant as unfavorable weather comes, resuming and finishing growth when the weather again becomes favorable. Most deciduous perennials grow during one portion of the year only, while most evergreen perennials make fresh growth during two distinct periods of the year, remaining dormant or being killed back during other portions of the year.

General Effects of Direct Sunshine

Direct sunshine has an effect upon plants different from the effect of diffuse sunlight at the same temperature. Any solid substance that intercepts the sun's rays becomes heated thereby to a greater or less degree. A shaded object does not become as warm as one exposed to the direct rays of the sun in an atmosphere of the same temperature. This is due to the absorption of radiant heat from the sun by the exposed object, as previously explained, while the shaded object becomes heated only by contact with the warmer atmosphere. In the shade, therefore, not only is the temperature of the air lower, but absorption of heat from the direct rays of the sun does not occur. Hence, the difference between the temperatures of the soil and of objects in direct sunshine, and of the soil and of objects in shade is considerably greater than the difference between the

temperature of the atmosphere over or about the exposed objects, and that over or about the shaded objects. Shutting off or admitting sunlight, therefore, has a double effect upon plants.

During weather too cool for the normal growth of a plant, direct sunshine promotes its activities and results in benefit, while shade has the opposite effect. The almost continuous bright sunshine of our winters is, therefore, a distinct advantage to vegetation and results in more rapid growth than could take place in a cloudy region where other conditions (both of soil and of weather) are the same. It has the effect, however, of unduly warming during the day deciduous trees in their leafless condition and causing some of them to bloom so early some years as to receive injury from frost.

During the warm portion of the year, parts of many plants become overheated in direct sunshine and injury to tissue results. This is especially true of the trunks of fruit trees which are exposed to the sun on the southwest side. Sometimes fruits, such as oranges, for example, will become sunburned and stunted in growth by exposure to the direct rays of the sun. Occasional injury to the leaves may occur, but injury to the stem is far more serious. Moreover, since the leaves are continually being cooled more or less by the evaporation of moisture from their tissues, they do not become as highly heated as do stems and tree trunks from which very little evaporation is taking place. Hence, plants with heavy foliage that shades the other parts have a distinct advantage, other things being equal, over ones with slight foliage, provided they are supplied with sufficient water.

Not only does insufficient or improperly located foliage result in the overheating of exposed stems and other parts, but the soil immediately about the plants becomes so highly heated as not only to seriously injure shallow roots but to radiate heat so rapidly that the effect of the direct rays of the sun is thereby much augmented. For two reasons, therefore, it is important that varieties of fruits, vegetables, and other crops be selected having a heavy foliage not sensitive to heat and that trees and shrubs be headed low. Protection to stems or trunks, to roots, and to the maturing crop of fruit or vegetables is thus secured.

Similar results are also obtained by close planting of vegetables, one plant thus shading its neighbor and all shading the soil. The crops for which such precautions are important are such as peas, beans, tomatoes, squashes, melons, and strawberries.

General Effects of Aridity and Rainfall

Of all the crops discussed in this bulletin, not over half a dozen grow better (other conditions being equally favorable) in a climate having a very low relative humidity. All the others thrive best in an atmosphere having a somewhat higher relative humidity than prevails in southern Arizona, providing all other conditions are favorable, and the growth of many is seriously retarded by the aridity of the region. Several crops, though the temperature be favorable, and though supplied with plenty of water, do not grow well during those portions of the year when the relative humidity is very low. Very rarely indeed is the atmosphere of the region too damp for the proper development of any crop.

As a water supply the direct effect of the local rainfall is not great, comparatively little benefit or injury to crops resulting from the small amount of water that falls. Indirectly, however, the local rains benefit many crops. The higher relative humidity that accompanies them is a benefit to most crops at any time of the year, and the lower temperatures that accompany the summer showers are a relief to most crops during that season. Local rains are ordinarily heartily welcomed, however, chiefly because as a rule rain falls at the same time in the region furnishing the supply of water for irrigation. Only occasionally is the local rainfall heavy enough to directly benefit the crops, and then only shallow-rooted ones are much benefited, since the soil is rarely wet to as great a depth as one foot during any one storm. When it is considered that the total annual rainfall of the region is only five to eight inches, much of which falls in such small amounts as to fail to reach the roots of plants, and that amounts ranging from 20 to 50 inches in depth are needed for the proper development of various crops, it will be evident that the effect of the local rainfall as a water supply is not great.

The combined effects of the factors discussed above—temperature, direct sunshine, relative humidity, and rainfall—together with that of the wind, are taken into consideration in discussing the crops whose relation to the weather is given in the pages that follow. Upon some crops the effect of one of these factors is greatest, upon others the effect of another is greatest.

VARIETIES

A Look into the Future

Varieties of crops originate in two chief ways. A new variety is either the result of intentional breeding and improvement by selection which had been carried on for a number of years, or it comes into existence by chance—*fortuitous variation*, as the scientists would say. In any event it is obvious that the characters on whose account the variety is considered valuable to man are (in nearly every case) first noticed at the place where the variety originates. The new form is therefore preserved and propagated because it has developed and displays some new and valuable characteristics under the climatic and soil conditions existing *at the place of its origin.*

The same variety, however, reacts very differently to the various stimuli produced by different environments. Hence we arrive at the commonly held and correct idea that each climatological area has its own peculiar set of varieties which succeed best under its own climatic and soil conditions. While these areas are only vaguely defined and overlap in many cases, we know of very many specific instances where differences in adaptation are unmistakable.

As most of the climatic divisions of the continent have at least some factors in common, the interchange and adoption of varieties from one to the other have gone on simultaneously with the development of local varieties. This process is of course taking place in the arid Southwest, of which Arizona and Sonora are a part, but with less satisfactory results, perhaps, than anywhere else. Of the seventy-two crops discussed in the succeeding pages, only about thirty-five have a variety which succeeds as well in the arid Southwest as elsewhere. Two reasons may be given to account for this state of affairs. In the first place, the climate has little in common with any other region, for here we find that lowest rainfall, lowest relative humidity, and greatest percentage of sunshine occur together; and this is true to the same extent of no other area of North America. In the second place the agricultural activities are so comparatively new that local varieties have not had time to develop.

These remarks lead us to the conclusion that the arid Southwest, of all the areas on the continent, is most in need of and will be most benefited by local varieties of crops which (like the Arizona Everbearing Strawberry) have been produced in the region. Whether they are intentionally produced or accidentally discovered, they

will be preserved and propagated for the sake of original values displayed under Arizona conditions and not because they may have a high color when grown in California or a fine flavor when grown in Michigan.

THE CROPS OF ARIZONA

(Arranged Alphabetically)

ALFALFA

As a commercial crop alfalfa has been grown in Arizona about forty-five years. It succeeds admirably in all parts of the State where suitable soil and sufficient water are available. It is little affected by altitudes encountered within the farming sections of the State. It succeeds in the Imperial Valley of California, below the sea level and on the farming lands around Prescott and Flagstaff at elevations of over 6,000 feet. When supplied with plenty of water it will make some growth in every month of the year in the lower valleys, but at the high elevations of northern and southeastern Arizona it is completely dormant in winter. Seven cuttings are the rule in the vicinity of Yuma, six cuttings in the Salt River Valley, five in the upper Gila Valley, and from three to four at high altitudes in the northern part of the State. Growth is most rapid in spring and early summer, and the second cutting is usually the heaviest. In midsummer, due to the intense heat and the attacks of leaf hoppers and the larvae of the alfalfa butterfly, the crop is usually light, but with the coming of the cooler weather of September, the growth is more vigorous. Varieties differ in this respect. The ordinary American and Turkestan types show most the effect of summer retardation of growth, whereas the Peruvian and Mediterranean alfalfas show least.

Alfalfa can be sown with a good chance of success during any month from September to May. If planted during the warmer months, the ground loses moisture so fast that it will dry out deeper than one dares to plant the seed before it has time to germinate. When the seed is again irrigated before coming up, the ground bakes around the seedlings so tightly that they are unable to force their way to the surface. Stands may be secured in the hottest weather, but in order to do so the seed must be planted shallow and then watered every two or three days until the plants are up. Such a proceeding would be impracticable in large

fields; alfalfa is, therefore, best planted during the cooler weather of fall, winter, or spring, when evaporation is not so great. The conditions are then usually such that the seed may be planted in a moist and well prepared seed bed that will retain its moisture long enough to bring up the plants without further irrigation. When, however, a second irrigation is necessary, the ground does not bake so quickly and the seedlings will, for the most part, get through the surface before a crust is formed. Good stands of alfalfa that were seeded in winter (late November to February 1) are common, but seeding during this season is risky on account of frost injury. If a hard freeze occurs soon after the alfalfa gets through the surface, when it has yet but two leaves, and especially when the soil is damp from recent irrigation or winter rains, a large proportion of the young plants may be killed. The writer knows of an instance where a beautiful stand of forty acres was destroyed in this way. After the young plants have three or more leaves, no degree of cold occurring in Arizona is likely to injure them.

Good stands can be secured during February and March. Spring planting, however, is open to the disadvantage that the young plants go into the hottest and driest parts of the summer (May and June) with poorly developed root systems. The tap-roots have not yet penetrated deeply and if a shortage of water should occur, which is more liable at this season than any other, the plants suffer from drought and the stand is apt to be seriously depleted. Moreover, spring-planted alfalfa gives but slight yields the first season and requires more frequent irrigation and greater attention than that which is planted earlier.

The best time to plant alfalfa is from September to November, inclusive, according to season and locality. Planted at this time, the young seedlings, favored by the mild temperatures of our autumn climate, get sufficient start not to be injured by the sharp frosts of December and January. The labor and expense of frequent irrigations are made unnecessary by low evaporation during the cool weather, and this is further reduced by the moisture obtained from whatever winter rains that may occur. While the tops grow but little during the cold season, the root systems are developing steadily. The alfalfa, therefore, goes into the hot, dry period of early summer with wide-spreading and deeply penetrating roots. This enables it to withstand heat and drought and return profitable yields even during the first year of its occupation of the soil.

Amount to sow.—Plump, well matured alfalfa seed should number about 200,000 to the pound. Where 15 pounds are sown to the

acre we would obtain 3,000,000 plants if all germinated. Estimating that under field conditions only two-thirds of the seeds produce plants, we would have 2,000,000 seedlings, or about 45 plants to the square foot. This number would be considered a good stand. As the plants grow older they crowd each other and some die. With an original stand of 45 plants to the square foot, more than half usually succumb during the first year. At two years 11 plants to the square foot is an abundant stand, and this will be normally reduced to an average stand of 5 to 6 plants by the end of 4 or 5 years.

In dry farming, the stand must necessarily be thinner on the ground (2 or 3 plants to the square foot) in order that each plant may secure an ample supply of water. For this reason many growers of alfalfa in semiarid sections find it best to sow not more than 8 to 10 pounds of seed to the acre. On the other hand, in humid sections where the danger of weeds is great, 20 pounds to the acre is not too much.

When it is intended that the field be devoted largely to the production of seed, not more than 10 to 12 pounds should be sown.

Varieties.—The natural adaptability of alfalfa and the wide range of soil and climatic conditions within which it has been grown, have resulted in many distinct types and races. Whenever alfalfa is grown for a long series of years in a given region from seed produced locally, it slowly becomes acclimatized. Those mixtures or variations which are best suited to the conditions prevailing flourish and crowd out the less favored individuals. Strains acclimatized to a given region are called regional varieties. In transferring seed from one country to another the measure of its success is usually proportional to the degree of similarity between the climatic factors of its old and new homes. However, unless we have definite information as to the exact origin of an imported strain, the length of time that it had been planted in that given region, and the local conditions under which it was grown, we must be very uncertain as to the likelihood of its value in Arizona. Not all strains of alfalfa from Turkestan, for example, have an equal value or climatic adaptation. Local conditions and the number of years they had been grown in that region will largely govern their quality.

As an example of an imported strain which has proven valuable, Peruvian alfalfa may be mentioned. The seed of this strain is now being produced in large quantities by the Yuma alfalfa seed growers. It is an upright, vigorous and very productive sort with narrow leaves and light purple flowers. Peruvian alfalfa is inclined

to be a little stemmy, and the plants are somewhat hairy, but these difficulties are largely overcome when it is grown in a thick stand.

Aside from the Peruvian, out of the 26 imported strains tested at this Station only four seem worthy of further trial. These include two from Europe and one each from South America and Turkestan. The strains from Arabia and the Mediterranean region were very promising for the first year or two of their growth in the experimental plots at Phoenix, but they soon lost stand to such an extent that their yields dropped below the margin of profit. The same difficulty has been experienced in other parts of Arizona where these strains have been tested. The Mediterranean alfalfas are vigorous, among the first to start in the spring, and the last in autumn to cease growth. For these reasons they will generally yield one more cutting to the season than any other variety, with the exception of the Peruvian. Were it not, therefore, for their tendency to lose stand, or if hardy strains of them could be developed, they would make a valuable introduction.

Finally, with regard to varieties, it may be stated that with the exception of the Peruvian alfalfa already mentioned, and in the absence of selected, tested, and purified strains of other sorts, our home-grown seed is probably better than any regional strain which we would be able to import indiscriminately at the present time. The fact that Arizona now is, and should continue to be, an exporter of high-grade alfalfa seed rather than an importer, perhaps more than anything else emphasizes the necessity of carefully guarding the purity of our local type and standard of excellence.

Cutting and curing.—The mowers should begin early in the morning, as soon as the dew is off, if such has fallen. As soon as the leaves are well withered, but before they become crisp, the hay should be raked into windrows. If the leaves are allowed to dry into a crisp before raking, many of them will shatter off and be lost in this operation and, moreover, the subsequent curing of the hay in the windrow or cock is not so satisfactory. The reason ascribed for this is that the evaporation from the withered leaves serves to extract water from the stems. If allowed to dry quickly into a crisp their condition is such that they are no longer able to do this. The stems therefore cure slowly and the haymaker must either allow the leaves to become so dry that they are for the most part lost by shattering, or else the stems must be put into the bale or stack with such high moisture content that injury by heating or moulding will occur.

From the windrow, alfalfa should be ready for stacking in two days and for baling in three days. The length of time required for curing will, of course, depend upon the temperature, the intensity of sunshine, and the amount of wind. A good rule is that hay is ready for stacking when water can no longer be twisted out of a wisp of stems held between the hands. It is not ready for baling, however, until such twisting will cause the stems to break.

Many farmers prefer to cure alfalfa in the cock rather than in the windrow. This method is more suited to the intensive farmer and to situations or times when there is danger of showers during the haying season. Hay in the cock resists the effect of rain better than in the windrow and is, moreover, in position to be protected by canvas or paper caps. Where the price of hay is high and the curing must be made in a rainy season, hay caps are frequently used with much profit. Caps made of canvas are preferable since they are more durable and are not blown off so badly by strong winds. Such caps, 40 inches square, weighted at the corners, can be manufactured especially for this purpose and sold at about 12 cents each.

The hay is usually allowed to remain in the windrow for one day, or until it is about half dry. It is then bunched with the rake or by hand, and thrown into cocks with the fork. Hay cocks are preferably as tall and narrow as possible to allow better circulation of air around and through them. Here the hay may remain three, four, or more days until it is thoroughly cured, whereupon it may be baled or stacked directly from the cock.

ALMONDS

Almonds have been grown with fair success and profit, especially when planted in large orchards where artificial protection of the bloom from spring frosts by smudging is practicable. Some varieties bloom during early February while others bloom several weeks later. The sharp frosts of midwinter and the warm, dry weather of spring and early summer, seem to supply just the climatic conditions needed by this nut. Of late years the prevalence of the disease known as crown gall (see Ariz.Sta.Timely Hint for Farmers No. 118) has caused the profit from almond culture to be very uncertain. Red spiders sometimes cause injury to the leaves, and birds often appropriate the nuts from isolated trees. The I. X. L. is, perhaps, the surest bearing variety, while the Nonpareil grows well and is

injured, one to four inches of the tips being killed. December 14, 1901, slight injury was done to the tips of *E. rudis* and *E. leucoxylon*, while year-old plants of *E. rostrata* were nearly all frozen to the ground, the minimum thermometers registering 15° F. at the ground, 20° F. in the government shelter, and 24° F. at the Weather Bureau. All are more or less checked in their growth by the heat of midsummer, *E. polyanthema* being affected perhaps the least of any of the species mentioned. Some species grow best in a moist atmosphere, but most of them prefer a dry atmosphere. With moderate irrigation, the Eucalypts noted above will endure well our hot, dry atmosphere.

Eucalypts may be grown from seed in a frame lattice house, the sides of which should be more or less protected with vines. The seeds should be sown by the middle of April or early in May in flats containing about 3 inches of clean fine sand. They should be scattered on the surface and covered with a thin layer of sand. The water used in irrigating should be free from alkali and the flats should be covered with one or two thicknesses of newspaper until the seedlings are mostly up. They must not be kept too wet, otherwise they will be attacked by a damping-off fungus. When the small plants have 4 or 6 leaves they may be transplanted in flats containing 5 or 6 inches of fine, sandy, loamy soil; and they should be watered regularly. About 100 plants may be set in a flat 12 by 20 inches in size. From July 1 to August 15 the flats of seedlings should be covered with fine wire screen or mosquito netting to keep June and Goldsmith beetles from depositing their eggs in the moist soil. The larvae of these insects eat the rootlets of young Eucalypts and may do a great amount of damage in a short time. The Eucalypts may remain in the lattice house during the winter season and be set out the following spring.

Eucalypts, like citrus trees, have two periods of thrifty growth, one from March to June, and the other from the latter part of August to the latter part of November. A little growth is made here by a few species during the hottest weather of summer, and a few make some growth during the coldest weather of winter.

The most rapid growing Eucalypt (*E. globulus*) does not endure well our extremes of climate, but the growth of *E. rudis*, *E. tereticornis*, and *E. rostrata* is fairly rapid. Judging by their growth upon the Farm and elsewhere, they can be counted on to attain a height of 30 feet and a diameter of 6 inches in four or five years, and a height of 50 feet and a diameter of 1 foot in six or eight years. A five-year-old *E. rudis* at the Farm measured 1 foot in diam-

eter and 40 feet high; an *E. tereticornis* of the same age was 30 feet high and 8 inches in diameter; and *E. rostrata* trees of this age were 35 feet high and 10 inches in diameter. In Phoenix, at the corner of Adams Street and Ninth Avenue, is an *E. rostrata* 16 years old, which is about 90 feet high and over 3 feet in diameter 5 feet from the ground.

Eucalypt trees have been thoroughly tested at the Experiment Station Farm at Phoenix and have been planted to a considerable extent in the Salt River and Colorado River valleys. They are better adapted to conditions in the Colorado River Valley than to those of the Salt River Valley. Of the 50 or 60 species tested at the Station Farm only 4 or 5 have proven well adapted to our climatic conditions. Of these, *Eucalyptus rudis*, *E. tereticornis*, and *E. rostrata* are among the valuable ones of the genus. *Eucalyptus rudis* was planted sparingly in the Upper Gila Valley and succeeded well during a few moderately favorable seasons. With rather cold weather the foliage was killed, and during a recent cold winter all the trees were killed to the ground. In the Santa Cruz Valley about Tucson, *Eucalyptus rudis*, *E. rostrata*, and *E. polyanthema* have made splendid growths and for a number of years were very promising for ornamental and economic purposes. Occasionally they were injured with the coldest weather, but this was not regarded as serious. During the winter of 1912–1913 the Eucalypt trees about Tucson were killed back seriously by the severe freezes, the lowest temperatures being 6° F. above zero. Since then they have not been planted extensively.

Eucalypt culture will probably never prove a success as a saw log industry in any part of Arizona. By planting the hardy species noted above, however, timber can be grown for fuel, fence posts, and, perhaps, for telegraph poles, railroad ties, and other purposes for which durable hardwood timber is used. In Arizona we must expect occasional severe winters which will materially damage Eucalyptus trees and result in the wood being harvested even in an immature condition, since fresh growth will begin from the base.

FETERITA

(*See under Grain Sorghums*)

FIGS

Figs are a satisfactory home orchard fruit in all our southern valleys except where the altitude is over 3500 feet. Above

2000 feet elevation it is desirable to protect the young trees by banking them with soil until they become established. It is doubtful if the fig will ever become a commercial crop in Arizona, unless, perhaps, in the Yuma Valley, where the first crop of a variety of black fig, probably the Mission, makes a semi-candied fig on the tree. This fig commands a high price on the market.

The Mission is the most valuable variety here because of its hardiness; because it does not need to be fertilized by the *Blastophaga* wasp, and because the first crop is important as well as the second.

The Brown Turkey and White Adriatic are good varieties which do not require the *Blastophaga* wasp to fertilize them. Bulletin Smyrna and Lob Injir are Smyrna varieties which, with the *Blastophaga* wasp to pollinate them, have produced abundant crops at Phoenix. With this class of figs it is necessary to raise the Capri fig trees, in the fruit of which the *Blastophaga* wasp develops. This is the only insect that can pollinate figs and the Capri is the only plant upon which the insect can develop.

Figs require a liberal supply of water and great care in transplanting. Methods used to transplant most trees will kill fig trees. The slightest drying of the roots kills the tree.

Figs grow readily from cuttings made from one-year-old wood. 9 to 12 inches long, planted to within one bud from the top. Cuttings need frequent irrigation.

GOOSEBERRIES

These humid climate loving plants succeed well in the mountains at high elevations. In the hot and dry southern valleys, however, their growth is attended with considerable difficulty and they have never been cultivated extensively with profit. The Houghton has been grown in an experimental way near Phoenix, but the prospects for a money profit in gooseberries are not encouraging.

GRAINS

Barley, wheat, and oats are not killed or seriously injured by the lowest temperatures that occur in southern Arizona. On the contrary, they continue to grow during most of the coolest weather of the year. Occasionally some injury is done to the bloom of grains during spring, but the loss from this cause is not great. It is the hot dry weather of summer that the small grains and most

of the perennial grasses can not endure, their growth being limited almost entirely by heat rather than by cold.

The season during which seed of the above grains germinates begins during September, after the mercury ceases to rise above 110° F. in the shade during the day, and begins falling as low as 50° to 60° at night, and continues until the next May when temperatures higher than the above occur. During the hot weather of June, July, and August the seed will not start, even though supplied with plenty of water.

Barley and early varieties of wheat sown and irrigated during September sometimes head out during December, especially if the autumn be warmer than usual; but ordinarily all grains head out by the end of April, regardless of the time of seeding. Fall-sown winter varieties of wheat do not usually begin stooling until after the coolest weather of winter is over, but most other grains begin stooling earlier, if sown during early fall. Grain sown during the latter part of January and during February makes an uninterrupted growth from the time of germination, and matures before the weather becomes extremely hot. Grain sown later then February does not have sufficient time for full growth before the hot weather of May and June. November is ordinarily the most favorable month for sowing grain. Evaporation being comparatively slow during the weather that follows, grain sown in moist soil during this month usually needs no irrigation until February or March if there is an average amount of winter rainfall. All sowings of all varieties ordinarily ripen during May or the few days that precede or follow this month. At this time of year the weather is usually very favorable for harvesting of the crop.

The principal grains sown are barley and wheat, though oats and rye are also successfully grown, but to a much smaller extent. The yield of grain is from 1500 to 3000 pounds per acre, depending upon the soil and water supply. The white varieties such as Sonora, Early Baart and White Australian are chiefly grown, although durum wheats produce well. Macaroni is probably the heaviest yielder, but is not used by the millers. Where grain is grown for poultry or stock feed, macaroni wheat is to be preferred. Among the bread wheats, Early Baart, a variety introduced by the Experiment Station about the year 1900, is now preferred by the millers on account of its high quality. It is now the most widely grown variety in the State. Marquis and Turkey Red will do well at the higher altitudes.

All varieties of barley do well. The variety of oats most widely grown is Texas Red.

For winter pasturage and an early crop of hay, barley, wheat, and oats are grown instead of the grasses used in cooler regions. These grains are sown both upon the fields of alfalfa and in freshly plowed soil. In the former case the seed is covered with a disk harrow. In fresh soil the seed is either disked or harrowed in. When sown upon alfalfa fields, seeding is usually done during early fall. In fresh soil seeding is done throughout fall and early winter. The resulting growth is commonly pastured during winter, and then permitted to grow up for hay during spring, being cut in April and May, when the kernels are quite well formed. Oats make the best hay, and they are now sown for this purpose more generally than formerly. The usual yield of grain hay is one and a half to three tons per acre.

GRAIN SORGHUMS

The sorghums are divided into two classes—the saccharine, used for syrup making or for forage, and the non-saccharine or grain sorghums, used for grain and forage.

The grain sorghums are of tropical origin, and flourish best in hot climates. They are very drought resistant, and well adapted to the semi-arid Southwest. They develop well with eight to ten inches of rainfall during the growing season.

Grain sorghums are divided into three classes, according to the character of head:

1. Kafir, with compact, erect heads.
2. Durra, with compact, pendant heads.
3. Broom corn type, with loose spreading heads.

The varieties of grain sorghums profitably grown in Arizona that belong to these classes are as follows:

Black-hull white Kafirs, dwarf and standard.

White milo or durra.

Yellow milo, usually called Milo Maize, dwarf and standard.

Feterita, one of the Durras.

Shallu, a broom corn type, sometimes called Egyptian wheat.

Kowliang, another broom corn type.

Kafir

The Kafirs, of which there are three varieties, the White, the Red, and the black hulled White, are very drought resistant. They

were introduced from South Africa and will endure for extended periods awaiting rainfall, without apparent injury to the plant. As soon as moisture is supplied Kafir will renew its growth and continue to mature its grain. The growing season for Kafir is about 120 days, or longer when growth is arrested by insufficient moisture. The date of planting in both irrigated and dry-farming sections should be as early as late spring frosts will permit. Under dry-farming conditions in the southern part of the State it is well to put the crop in as early as March 10 to 15 in order to take advantage of winter moisture.

Black-hull White Kafir is the most popular variety grown in Arizona both for grain and silage purposes.

Milo Maize

The term Durra is so little used that this group is considered as Milo Maize. The Durras include white, brown and yellow milos and are characterized by large flat seeds. Feterita, a more recent introduction, also belongs to the Durra group.

This group of grain sorghums was introduced from North Africa. Like Kafir, Milo Maize flourishes in the hot dry climate of Arizona. The time required to produce a crop of yellow milo is about 100 days or nearly three weeks shorter then Kafir. The Milos are better grain producers than the Kafirs, but are not as good forage crops.

Dwarf types of milo have been developed superior to the tall or standard types for production of grain. Under dry-farming conditions the Milos should be planted in July in southern Arizona. The summer rains begin at this time and the season is long enough after that date to mature a crop. In the northern part of the State, where these crops are grown by dry-farming, planting should be made about May 1.

In the irrigated sections the Milos should be planted in April. Two crops of milo can be harvested from the April planting. The first crop can be cut in early July and used for forage or silage, and from the stumps a second crop will be produced before the frosts in November.

Feterita

Feterita is a variety of Durra with erect heads, white seeds and black hulls. This variety is of recent introduction and shows superiority over the Kafirs in drought resistance, and in shorter length

of time required to produce a crop. Under favorable conditions and with an optimum water supply, a grain crop of feterita can be produced in 90 days. Under dry-farming Feterita is a very valuable crop for forage or grain, when necessary to plant as late as July. Early planting is not recommended for this crop under irrigation or dry-farming, unless two crops are desired in one season. The Kafirs are superior for forage and where that is desired and planting can be done in March or April, they are to be preferred to Feterita. The greatest value of Feterita will come through its use as a dry-farming crop for summer planting.

Shallu (Egyptian Wheat)

Shallu is one of the broom corn sorghums. It is not extensively grown in Arizona. Some of it is grown under irrigation for chicken feed. As a forage plant it is not equal to the Kafirs or to the Milos. It was introduced from India. It is not recommended for dry land farming in this State. Under irrigation planting should be made in April and May.

Kowliang

Kowliang is another broom corn sorghum recently introduced from China and Manchuria. It will grow farther north than some other grain sorghums. Kowliang should be planted in April or May under irrigation, and as early as frost will permit under dry-farming.

GRAPES

The European, or *vinifera*, grape is admirably suited to the southern part of the State. Almost any of these *vinifera* varieties, including table, raisin, and wine grapes, will develop well, but in this State table grapes interest us more than the wine or raisin varieties. Our weather does not permit of raisin making in some seasons, and the law will not allow us to make wine. The characteristics of the European grape in our hot valleys are early ripening and high sugar content. Our grapes become sweet before they are ripe, which results in too early picking by the grower.

Successful European grape culture requires a long growing season, such as is generally found at elevations below 5000 feet in the southern half of the State, and under 4000 feet in the northern half of the State. Grapes will grow in a variety of soils and with moderate irrigation. An easily worked soil is preferred. Vines

should be set 6 by 8 or 8 by 8 feet apart. During the first two years the development of a single string trunk is desired, if the stump or self-supporting system of pruning is used. After the trunk is formed three or four arms are developed which carry the fruiting canes or spurs and the renewal spurs. Subsequent pruning consists in thinning the canes to the required number and the shortening-in of these canes according to the variety; also the leaving of renewal spurs to form the fruiting wood for the next crop.

The stump system has several disadvantages, but it is an easy one to establish and maintain and allows cultivation in two directions, which advantages make it the most popular system. It is better fitted to the varieties which bear well on spurs like the Mission, than to varieties like Thompson's Seedless, which need canes upon which to bear a full crop. A trellis is best for this and other long-pruned varieties.

It has not as yet been necessary to graft vines in Arizona to resist the phylloxera. Insects are not very numerous, the Buffalo leaf hopper and the green beetles being the worst.

Thompson's Seedless is easily the most popular grape, because it ripens early enough to escape the green beetles and is seedless. Other popular varieties are Mission, Muscat, and Malaga. The Dattier de Beyreuth, Almeria, Lady Finger, and Purple Damascus are also worthy of trial.

In the cool sections of the State the American or American-European hybrid varieties of grapes can be grown. The best of these varieties for our conditions is Niagara. Other varieties are Agawam, Woodruff, and Concord. Although these varieties can be grown in the warm parts of the State, the vines are not very healthy and the yield is low.

GRASSES

Brome grass, Kentucky blue grass, Australian rye grass, orchard grass, and other similar cultivated grasses so common in the Central and Eastern states are seriously injured or killed outright by our hot, dry summers at altitudes below 3000 feet. They make good growth, however, during nearly all of the fall, winter, and spring seasons. Seeds of such grasses should be sown in September or early in October when the maximum temperatures are considerably lower than in summer. During June and July the seeds of these

grasses will not germinate, ordinarily, even though given abundant irrigation.

Johnson grass and Bermuda grass are considered by farmers to be the two chief weed pests of the region. Both are dormant in winter, but grow vigorously throughout the summer. Bermuda grass is a fair lawn grass and presents a good appearance during the heat of summer when blue grass is either dead or in very poor condition. A good combination for lawns for the warmer valleys of the State is Bermuda grass and Australian rye grass, the former for summer growing and the latter for winter and spring. Australian rye grass is an annual under our climatic conditions, and is sown thickly and raked into Bermuda grass sod in September. With abundant irrigation it germinates readily and soon forms a velvety carpet which should be mowed during the winter and spring months. In early summer the rye grass dies out and is gradually replaced by Bermuda grass.

White clover is used to some extent for lawn purposes. It endures a wide range of temperatures since it grows both in summer, when it requires abundant and heavy irrigation, and in winter. Like blue grass it grows best in partly shaded lawns at altitudes below 2500 feet. Above altitudes of 3000 feet both these lawn plants grow well with most ordinary care. *Lippia nodiflora*, a member of the Verbena family, also grows well at lower altitudes for lawn purposes. This is a low trailing plant with an abundance of small, whitish flowers resembling those of the white clover. It will grow with less water than most other lawn plants and thrives in shallow soils that contain considerable broken caliche. It does best with moderate irrigation and should be cut with a lawn mower the same as lawn grasses.

Rhodes grass and Sudan grass have been introduced recently and are very promising as forage crops. Rhodes grass is believed to be native to southern Africa and is injured with winter temperatures of 5° F. or lower. It spreads from its roots by means of stolons which grow above ground and in a single season it usually forms a continuous turf. There is no danger of its becoming a pest like Johnson grass since with one plowing it can be eradicated. It has not been grown in rich alluvial soils, but in ordinary mesa soil on the University grounds it has outyielded alfalfa several times, and with the most ordinary care makes a growth from early spring until late fall. Its heaviest growth appears to be made in July and August.

Sudan grass very much resembles Johnson grass. It is an annual plant, however, and has no rootstocks or underground stems of any kind. Its yields are heavy and where it has been grown as a crop it has given satisfactory results. The forage is rather coarse though much relished by stock. It grows best during the hot summer weather and is quite drought resistant. During the summer of 1913, the yields of this plant at the Experiment Station Farm at Phoenix were at the rate of 8 tons per acre from two cuttings. It also produces heavy crops of seed. This is desirable since the plant has to be sown annually.

GUAVAS

These tropical fruits are too sensitive to cold to be grown even in the warmest parts of the State. The common guava requires some protection during our mildest winters. The strawberry guava is somewhat hardier, but even this can not be grown satisfactorily in the Salt and Lower Colorado River valleys. One should not plant out fruits as tender as the guava unless he is well prepared to care for them in winter.

KAFIR AND EGYPTIAN CORN

(*See under Grain Sorghums*)

KOWLIANG

(*See under Grain Sorghums*)

LEMONS

The climate of Arizona is not as well suited to the culture of lemons as to oranges. The lemon is more tender, and to produce continually, as a commercial crop should, requires an equable climate near the coast. In a very few places in the Salt River and Yuma valleys, where the mercury does not drop below 25° F., the lemon can be grown for local consumption. In these valleys it will not produce fruit in summer when the fruit is in greatest demand.

Orchards should be heated when the temperature drops below 28° F. It is customary to start the heaters when the temperature gets a degree or two below freezing if it gets this cold before 12 or 1 o'clock a. m. The mercury generally falls until about 4 a. m. on a still night. It is easier to keep the temperature of the trees at

a given point by heating early than it is to raise the temperature after it has once fallen. Trees for home use should be planted in a protected place near buildings or other trees. The Eureka is the best market variety, but Villa Franca, Lisbon, and Sicily are good producers.

LETTUCE

Head lettuce is destined to become a commercial truck crop in Southern Arizona. It thrives in an arid climate if plenty of irrigating water is available. The quality of the crop can not be surpassed when the right variety is grown.

The growing conditions necessary for the production of lettuce are a cool growing season, ranging from not over 85° F. to not less than 20°; a rich, easily worked soil which will promote rapid growth; early thinning of the plants; frequent cultivation; and adequate irrigation, especially in warm weather.

In the southern part of the State seed should be sown in place any time from September to January. The plants should be thinned to 12 inches as soon as they have three or four leaves Delay in this checks the growth and increases the cost of the work. In cultivation, care should be exercised not to throw soil into the heads. A sandy soil is objectionable because the sand blows into the heads. Head lettuce can be had in the subtropical portions of the State from Thanksgiving until April. In cooler locations it is grown as an early spring crop. Hot weather causes lettuce to stop growing, become bitter, and send up a seed stalk.

The varieties which succeed best are those with the crinkled leaves. New York or Los Angeles, Iceberg and Denver Market are of this type, named in the order of their popularity. The smooth-leaved lettuces, like Big Boston, Tennis Ball, Salamander, etc., are so much inferior in this climate to the other varieties named that it is not advisable to grow them. Cos or Romaine lettuce and varieties of loose-leaf lettuce also grow well, but are not to be compared with either New York or Iceberg.

LOQUATS

Loquats are easily grown in the valleys in the southern parts of the State, below altitudes of 2500 feet. They bloom from November to January and, ordinarily, the flowers are killed by frost.

These trees are among the finest broad-leaf evergreens and are handsome ornamentals. When planted against a house or in protected situations the flowers and fruits are much less likely to be injured with frost, so that occasionally a good crop of fruit is produced. During the winter of 1912–1913 the foliage of loquats was not injured with a temperature of 6° F. Loquats are tolerant to our extreme heat and aridity, the foliage showing almost no bad effects in summer.

MILLET

Most varieties of millet can be grown readily, although the yield is not as great as in some cooler regions. The ordinary varieties are sown during August and harvested during the fall, as in other regions. German millet is most generally grown, being resistant to heat and drought. Pearl millet may be planted in the spring and will grow luxuriantly all summer, but does not seem as desirable for a forage crop as sorghum.

MILO MAIZE

(See under Grain Sorghums)

MULBERRIES

Mulberries are easily grown here, nearly all varieties thriving under our conditions. They are among the earliest of our trees to leaf out and to ripen fruit. Mulberries would be very desirable for shade trees were it not for the litter made by their fruit falling on the ground. This attracts flies and is annoying underfoot. Nurserymen are now propagating mulberries that are said to produce only staminate flowers. Such trees would be especially valuable for avenue planting. The heavy fruiting mulberry trees are valuable for planting in poultry yards because of their dense shade and spreading branches among which poultry may roost. Hogs are also fond of mulberries. The most desirable varieties for planting are the Downing Everbearing, New American White, Russian, and Persian or black mulberry. The Downing Everbearing mulberry has large long-pointed leaves that are dull green on the upper side. It is a form of *Morus multicaulis*. The New American is a form of the white mulberry. Its leaves are glossy above, large, and short-pointed. The Russian mulberry is a very hardy form of the white mulberry, usually having deeply cut leaves. It does not grow as large as the white mulberry, but

is hardy and is highly recommended for planting under dry farming conditions. The Persian mulberry branches from near the ground with stout, spreading limbs. The leaves are large and dull green. The fruits are broad and slightly hairy. When ripe they are black, juicy and tart, and are excellent for table use.

MUSKMELONS (CANTALOUPES)

The two terms are often used interchangeably, since there is no real distinction between them. In the West it is customary to call the small, round, netted melon the cantaloupe, and the large, oblong or flattened, netted or smooth melons, muskmelons. Both types are grown in the same way, the cantaloupe being far more popular than the muskmelon.

The cantaloupe or muskmelon requires a rich loam soil, preferably a sod soil, for its best development, a warm growing season, plenty of water, dry air, and plenty of sunshine during the ripening period.

The seed is planted as soon as danger of frost is over, the hills being placed about 4 to 6 feet apart with 8 to 12 seed placed in a hill along the water line of furrows to insure prompt germination. As soon as danger of insect damage to the seedlings is past, the plants are thinned to 2 or 3 in a hill. If the ground is foul with weeds or Bermuda grass the hills should be checked and cultivated in both directions. As the vines begin to run, the irrigation furrows should be moved away from the rows. The crop reaches maturity in from 80 to 120 days, depending on the weather and the variety.

Plantings of cantaloupes made in July in the southern part of the State are profitable if the aphids or plant lice do not take the crop. These lice are very difficult to control and are nearly always present. Tobacco spray, if thoroughly applied every week before the lice appear, will generally keep them in subjection.

The most popular varieties are Rockyford, Burrell's Gem, Nutmeg, Early Waters and Early Hackensack.

OATS

(*See under Grains*)

OLIVES

Olives are peculiarly well adapted to southern Arizona conditions. They are never injured by our summer heat and very

rarely is the fruit injured by cold. On account of the bright sunlight and dryness of the atmosphere, the trees are free from the scale insects which cause so much damage in moister climates. The trees grow vigorously, bear heavily, the fruit is large and the content of oil is high. Some varieties mature their fruit in October and November, while others will hold their fruit in good condition for oil making until June of the following year. Olive culture, both for pickles and oil, promises to be one of the standard and profitable industries of the region. The varieties best suited for pickles are Mission, Manzanillo, and Sevillano. The varieties best suited for oil making are Mission, Correggiola, Nevadillo, Pendulina, and others.

ONIONS

This crop is easily grown in southern Arizona as a winter crop, and in northern Arizona as a spring and summer crop. It is a profitable truck crop in most sections of the State, although prices may drop below the cost of production in June when growers are endeavoring to dispose of their entire crop at once. Bermuda, the type of onion best suited to this region, is not a good keeper, although when carefully handled and cured on racks in a house where sulphur may be burned, it will usually keep until fall. The cool valleys in the northern part of the State should produce onions for southern markets from fall until June. The supply at present comes from California.

The method of growing generally employed in the southern part of the State, is to sow the seed in seed-beds between August and October, and when the plants are the size of a lead pencil transplant into narrow borders which can be flooded. They are set 2 to 4 inches apart in rows 12 to 14 inches apart. With efficient management the cost of growing the plants and transplanting them need not exceed $35 per acre. Some growers prefer to sow the seed in place, planting two rows on a ridge. To avoid thinning with this method, an accurate knowledge of the viability of the seed and a careful adjustment of the seeder is necessary.

Growers in the northern valleys who wish to raise onions by the transplanting method, should arrange with a gardener in the Salt River Valley to grow their plants out of doors. Otherwise they should be grown in hotbeds, which is a more expensive method. A good loam soil, preferably enriched with rotted manure, well leveled, cultivated with a wheel hoe at frequent intervals, and irrigated as required, are essential to a successful crop.

Crystal Wax, White Bermuda, Yellow and Red Bermuda, and Australian Brown are the most popular varieties. Australian Brown is the best keeper, but it is not a sure crop in the warmest valleys. Yellow Danvers is successfully grown in the cool sections.

ORANGES

While oranges are being grown to an increasing extent on the upper slopes of the Salt River Valley, on the mesa near Yuma, and in some other localities, the area in Arizona where their culture may be profitably engaged in is quite limited when compared with the total of cultivated land. Orange trees being semitropical evergreens are severely injured when the mercury falls to 20°, and 16° will often kill the trees to the ground. The intense heat of summer is also very apt to injure the trunks unless the trees are headed low and properly pruned. For these reasons orange culture requires more skill and is attended with somewhat greater expense than in other orange growing localities. The incentive to grow oranges in a commercial way under these conditions is the high price received in the eastern markets for the Washington Navel variety, which ripens its fruit somewhat in advance of the California crop.

Partly on account of the hot dry climate citrus trees are not at present infested with scale insects. The chief insect enemies of the orange are several species of thrips of which *Euthrips tritici* is by far the most common. They distort the foliage and scar the fruit with considerable detriment to its selling value. Washington Navel is perhaps the most profitable variety. Valencia, Ruby, St. Michaels, Jaffa, and Mediterranean Sweet are also grown.

PEACHES

The different varieties of peaches differ considerably in their relation to the climatic conditions of the region. Some varieties escape injury from frosts most seasons and endure well the heat of summer. These varieties belong mostly to the Chinese type of peaches, blooming so early during the winter that the young fruit has attained sufficient size to endure quite low temperatures. As a result they set full of fruit every year. Other varieties not only receive considerable injury from spring frosts, but do not endure well the heat of summer. Peach trees are longer lived than apple or plum trees, but not so long-lived as either apricots or almonds,

usually remaining productive ten or twelve years from time of setting.

On account of the prevalence of spring frosts peaches are a very uncertain crop in exposed situations in the mountains. Some varieties of peaches are seriously injured by thrips which attack the winter buds just as they are unfolding in the spring. Those varieties which ripen their crop in the middle of the heated season suffer seriously from the *Allorhina* beetle. Ripe peaches are also very difficult to handle and market during very hot weather. The chief disease of the peach in Arizona is the crown gall of the roots which often does very serious damage (See Ariz. Sta. Bull. 33). Very few peaches are dried in the region for the same reason as given under "Figs." A very large list of peaches does well in the southern valleys, among which the following have been found to be especially desirable: Admiral Dewey, Alexander, Briggs May, Late Crawford, Elberta, Salway, Wheatland, Sylphide Cling, Krummel, St. John and Belle of Georgia.

PEANUTS

Peanuts may be grown in the lower irrigated valleys. They should be planted as soon as danger of frost is over; and mature five or six months after planting. They do best in sandy soils, require frequent irrigation and should be harvested as soon as yellow vines indicate maturity, to avoid sprouting the crop. The Spanish variety yields a heavy crop of small nuts. Virginia Red produces well if sufficiently irrigated. Indian Runner yields under less favorable conditions than Virginia Red. In addition to their uses as human food, peanuts make excellent hay. Being leguminous in character, the crop is beneficial to the soils upon which it is grown.

PEARS

Pears are well suited to all parts of Arizona, except in the very frosty mountain sections. They thrive in a heavy soil, bloom late compared with the stone fruits, and so usually escape damage by frost. On account of late blooming the pear can be planted in valleys where other fruits are less certain, and where the pear finds soil conditions better than on uplands where the soil is lighter.

The fire blight, which is so destructive in practically all pear-growing sections, is not so severe in our arid climate as it is in humid sections. Nevertheless, it can do very severe damage in this State,

injured, one to four inches of the tips being killed. December 14, 1901, slight injury was done to the tips of *E. rudis* and *E. leucoxylon*, while year-old plants of *E. rostrata* were nearly all frozen to the ground, the minimum thermometers registering 15° F. at the ground, 20° F. in the government shelter, and 24° F. at the Weather Bureau. All are more or less checked in their growth by the heat of midsummer, *E. polyanthema* being affected perhaps the least of any of the species mentioned. Some species grow best in a moist atmosphere, but most of them prefer a dry atmosphere. With moderate irrigation, the Eucalypts noted above will endure well our hot, dry atmosphere.

Eucalypts may be grown from seed in a frame lattice house, the sides of which should be more or less protected with vines. The seeds should be sown by the middle of April or early in May in flats containing about 3 inches of clean fine sand. They should be scattered on the surface and covered with a thin layer of sand. The water used in irrigating should be free from alkali and the flats should be covered with one or two thicknesses of newspaper until the seedlings are mostly up. They must not be kept too wet, otherwise they will be attacked by a damping-off fungus. When the small plants have 4 or 6 leaves they may be transplanted in flats containing 5 or 6 inches of fine, sandy, loamy soil; and they should be watered regularly. About 100 plants may be set in a flat 12 by 20 inches in size. From July 1 to August 15 the flats of seedlings should be covered with fine wire screen or mosquito netting to keep June and Goldsmith beetles from depositing their eggs in the moist soil. The larvae of these insects eat the rootlets of young Eucalypts and may do a great amount of damage in a short time. The Eucalypts may remain in the lattice house during the winter season and be set out the following spring.

Eucalypts, like citrus trees, have two periods of thrifty growth, one from March to June, and the other from the latter part of August to the latter part of November. A little growth is made here by a few species during the hottest weather of summer, and a few make some growth during the coldest weather of winter.

The most rapid growing Eucalypt (*E. globulus*) does not endure well our extremes of climate, but the growth of *E. rudis*, *E. tereticornis*, and *E. rostrata* is fairly rapid. Judging by their growth upon the Farm and elsewhere, they can be counted on to attain a height of 30 feet and a diameter of 6 inches in four or five years, and a height of 50 feet and a diameter of 1 foot in six or eight years. A five-year-old *E. rudis* at the Farm measured 1 foot in diam-

eter and 40 feet high; an *E. tereticornis* of the same age was 30 feet high and 8 inches in diameter; and *E. rostrata* trees of this age were 35 feet high and 10 inches in diameter. In Phoenix, at the corner of Adams Street and Ninth Avenue, is an *E. rostrata* 16 years old, which is about 90 feet high and over 3 feet in diameter 5 feet from the ground.

Eucalypt trees have been thoroughly tested at the Experiment Station Farm at Phoenix and have been planted to a considerable extent in the Salt River and Colorado River valleys. They are better adapted to conditions in the Colorado River Valley than to those of the Salt River Valley. Of the 50 or 60 species tested at the Station Farm only 4 or 5 have proven well adapted to our climatic conditions. Of these, *Eucalyptus rudis*, *E. tereticornis*, and *E. rostrata* are among the valuable ones of the genus. *Eucalyptus rudis* was planted sparingly in the Upper Gila Valley and succeeded well during a few moderately favorable seasons. With rather cold weather the foliage was killed, and during a recent cold winter all the trees were killed to the ground. In the Santa Cruz Valley about Tucson, *Eucalyptus rudis*, *E. rostrata*, and *E. polyanthema* have made splendid growths and for a number of years were very promising for ornamental and economic purposes. Occasionally they were injured with the coldest weather, but this was not regarded as serious. During the winter of 1912–1913 the Eucalypt trees about Tucson were killed back seriously by the severe freezes, the lowest temperatures being 6° F. above zero. Since then they have not been planted extensively.

Eucalypt culture will probably never prove a success as a saw log industry in any part of Arizona. By planting the hardy species noted above, however, timber can be grown for fuel, fence posts, and, perhaps, for telegraph poles, railroad ties, and other purposes for which durable hardwood timber is used. In Arizona we must expect occasional severe winters which will materially damage Eucalyptus trees and result in the wood being harvested even in an immature condition, since fresh growth will begin from the base.

FETERITA

(*See under Grain Sorghums*)

FIGS

Figs are a satisfactory home orchard fruit in all our southern valleys except where the altitude is over 3500 feet. Above

2000 feet elevation it is desirable to protect the young trees by banking them with soil until they become established. It is doubtful if the fig will ever become a commercial crop in Arizona, unless, perhaps, in the Yuma Valley, where the first crop of a variety of black fig, probably the Mission, makes a semi-candied fig on the tree. This fig commands a high price on the market.

The Mission is the most valuable variety here because of its hardiness; because it does not need to be fertilized by the *Blastophaga* wasp, and because the first crop is important as well as the second.

The Brown Turkey and White Adriatic are good varieties which do not require the *Blastophaga* wasp to fertilize them. Bulletin Smyrna and Lob Injir are Smyrna varieties which, with the *Blastophaga* wasp to pollinate them, have produced abundant crops at Phoenix. With this class of figs it is necessary to raise the Capri fig trees, in the fruit of which the *Blastophaga* wasp develops. This is the only insect that can pollinate figs and the Capri is the only plant upon which the insect can develop.

Figs require a liberal supply of water and great care in transplanting. Methods used to transplant most trees will kill fig trees. The slightest drying of the roots kills the tree.

Figs grow readily from cuttings made from one-year-old wood. 9 to 12 inches long, planted to within one bud from the top. Cuttings need frequent irrigation.

GOOSEBERRIES

These humid climate loving plants succeed well in the mountains at high elevations. In the hot and dry southern valleys, however, their growth is attended with considerable difficulty and they have never been cultivated extensively with profit. The Houghton has been grown in an experimental way near Phoenix, but the prospects for a money profit in gooseberries are not encouraging.

GRAINS

Barley, wheat, and oats are not killed or seriously injured by the lowest temperatures that occur in southern Arizona. On the contrary, they continue to grow during most of the coolest weather of the year. Occasionally some injury is done to the bloom of grains during spring, but the loss from this cause is not great. It is the hot dry weather of summer that the small grains and most

of the perennial grasses can not endure, their growth being limited almost entirely by heat rather than by cold.

The season during which seed of the above grains germinates begins during September, after the mercury ceases to rise above 110° F. in the shade during the day, and begins falling as low as 50° to 60° at night, and continues until the next May when temperatures higher than the above occur. During the hot weather of June, July, and August the seed will not start, even though supplied with plenty of water.

Barley and early varieties of wheat sown and irrigated during September sometimes head out during December, especially if the autumn be warmer than usual; but ordinarily all grains head out by the end of April, regardless of the time of seeding. Fall-sown winter varieties of wheat do not usually begin stooling until after the coolest weather of winter is over, but most other grains begin stooling earlier, if sown during early fall. Grain sown during the latter part of January and during February makes an uninterrupted growth from the time of germination, and matures before the weather becomes extremely hot. Grain sown later then February does not have sufficient time for full growth before the hot weather of May and June. November is ordinarily the most favorable month for sowing grain. Evaporation being comparatively slow during the weather that follows, grain sown in moist soil during this month usually needs no irrigation until February or March if there is an average amount of winter rainfall. All sowings of all varieties ordinarily ripen during May or the few days that precede or follow this month. At this time of year the weather is usually very favorable for harvesting of the crop.

The principal grains sown are barley and wheat, though oats and rye are also successfully grown, but to a much smaller extent. The yield of grain is from 1500 to 3000 pounds per acre, depending upon the soil and water supply. The white varieties such as Sonora, Early Baart and White Australian are chiefly grown, although durum wheats produce well. Macaroni is probably the heaviest yielder, but is not used by the millers. Where grain is grown for poultry or stock feed, macaroni wheat is to be preferred. Among the bread wheats, Early Baart, a variety introduced by the Experiment Station about the year 1900, is now preferred by the millers on account of its high quality. It is now the most widely grown variety in the State. Marquis and Turkey Red will do well at the higher altitudes.

All varieties of barley do well. The variety of oats most widely grown is Texas Red.

For winter pasturage and an early crop of hay, barley, wheat, and oats are grown instead of the grasses used in cooler regions. These grains are sown both upon the fields of alfalfa and in freshly plowed soil. In the former case the seed is covered with a disk harrow. In fresh soil the seed is either disked or harrowed in. When sown upon alfalfa fields, seeding is usually done during early fall. In fresh soil seeding is done throughout fall and early winter. The resulting growth is commonly pastured during winter, and then permitted to grow up for hay during spring, being cut in April and May, when the kernels are quite well formed. Oats make the best hay, and they are now sown for this purpose more generally than formerly. The usual yield of grain hay is one and a half to three tons per acre.

GRAIN SORGHUMS

The sorghums are divided into two classes—the saccharine, used for syrup making or for forage, and the non-saccharine or grain sorghums, used for grain and forage.

The grain sorghums are of tropical origin, and flourish best in hot climates. They are very drought resistant, and well adapted to the semi-arid Southwest. They develop well with eight to ten inches of rainfall during the growing season.

Grain sorghums are divided into three classes, according to the character of head:

1. Kafir, with compact, erect heads.
2. Durra, with compact, pendant heads.
3. Broom corn type, with loose spreading heads.

The varieties of grain sorghums profitably grown in Arizona that belong to these classes are as follows:

Black-hull white Kafirs, dwarf and standard.
White milo or durra.
Yellow milo, usually called Milo Maize, dwarf and standard.
Feterita, one of the Durras.
Shallu, a broom corn type, sometimes called Egyptian wheat.
Kowliang, another broom corn type.

Kafir

The Kafirs, of which there are three varieties, the White, the Red, and the black hulled White, are very drought resistant. They

were introduced from South Africa and will endure for extended periods awaiting rainfall, without apparent injury to the plant. As soon as moisture is supplied Kafir will renew its growth and continue to mature its grain. The growing season for Kafir is about 120 days, or longer when growth is arrested by insufficient moisture. The date of planting in both irrigated and dry-farming sections should be as early as late spring frosts will permit. Under dry-farming conditions in the southern part of the State it is well to put the crop in as early as March 10 to 15 in order to take advantage of winter moisture.

Black-hull White Kafir is the most popular variety grown in Arizona both for grain and silage purposes.

Milo Maize

The term Durra is so little used that this group is considered as Milo Maize. The Durras include white, brown and yellow milos and are characterized by large flat seeds. Feterita, a more recent introduction, also belongs to the Durra group.

This group of grain sorghums was introduced from North Africa. Like Kafir, Milo Maize flourishes in the hot dry climate of Arizona. The time required to produce a crop of yellow milo is about 100 days or nearly three weeks shorter then Kafir. The Milos are better grain producers than the Kafirs, but are not as good forage crops.

Dwarf types of milo have been developed superior to the tall or standard types for production of grain. Under dry-farming conditions the Milos should be planted in July in southern Arizona. The summer rains begin at this time and the season is long enough after that date to mature a crop. In the northern part of the State, where these crops are grown by dry-farming, planting should be made about May 1.

In the irrigated sections the Milos should be planted in April. Two crops of milo can be harvested from the April planting. The first crop can be cut in early July and used for forage or silage, and from the stumps a second crop will be produced before the frosts in November.

Feterita

Feterita is a variety of Durra with erect heads, white seeds and black hulls. This variety is of recent introduction and shows superiority over the Kafirs in drought resistance, and in shorter length

of time required to produce a crop. Under favorable conditions and with an optimum water supply, a grain crop of feterita can be produced in 90 days. Under dry-farming Feterita is a very valuable crop for forage or grain, when necessary to plant as late as July. Early planting is not recommended for this crop under irrigation or dry-farming, unless two crops are desired in one season. The Kafirs are superior for forage and where that is desired and planting can be done in March or April, they are to be preferred to Feterita. The greatest value of Feterita will come through its use as a dry-farming crop for summer planting.

Shallu (Egyptian Wheat)

Shallu is one of the broom corn sorghums. It is not extensively grown in Arizona. Some of it is grown under irrigation for chicken feed. As a forage plant it is not equal to the Kafirs or to the Milos. It was introduced from India. It is not recommended for dry land farming in this State. Under irrigation planting should be made in April and May.

Kowliang

Kowliang is another broom corn sorghum recently introduced from China and Manchuria. It will grow farther north than some other grain sorghums. Kowliang should be planted in April or May under irrigation, and as early as frost will permit under dry-farming.

GRAPES

The European, or *vinifera*, grape is admirably suited to the southern part of the State. Almost any of these *vinifera* varieties, including table, raisin, and wine grapes, will develop well, but in this State table grapes interest us more than the wine or raisin varieties. Our weather does not permit of raisin making in some seasons, and the law will not allow us to make wine. The characteristics of the European grape in our hot valleys are early ripening and high sugar content. Our grapes become sweet before they are ripe, which results in too early picking by the grower.

Successful European grape culture requires a long growing season, such as is generally found at elevations below 5000 feet in the southern half of the State, and under 4000 feet in the northern half of the State. Grapes will grow in a variety of soils and with moderate irrigation. An easily worked soil is preferred. Vines

should be set 6 by 8 or 8 by 8 feet apart. During the first two years the development of a single string trunk is desired, if the stump or self-supporting system of pruning is used. After the trunk is formed three or four arms are developed which carry the fruiting canes or spurs and the renewal spurs. Subsequent pruning consists in thinning the canes to the required number and the shortening-in of these canes according to the variety; also the leaving of renewal spurs to form the fruiting wood for the next crop.

The stump system has several disadvantages, but it is an easy one to establish and maintain and allows cultivation in two directions, which advantages make it the most popular system. It is better fitted to the varieties which bear well on spurs like the Mission, than to varieties like Thompson's Seedless, which need canes upon which to bear a full crop. A trellis is best for this and other long-pruned varieties.

It has not as yet been necessary to graft vines in Arizona to resist the phylloxera. Insects are not very numerous, the Buffalo leaf hopper and the green beetles being the worst.

Thompson's Seedless is easily the most popular grape, because it ripens early enough to escape the green beetles and is seedless. Other popular varieties are Mission, Muscat, and Malaga. The Dattier de Beyreuth, Almeria, Lady Finger, and Purple Damascus are also worthy of trial.

In the cool sections of the State the American or American-European hybrid varieties of grapes can be grown. The best of these varieties for our conditions is Niagara. Other varieties are Agawam, Woodruff, and Concord. Although these varieties can be grown in the warm parts of the State, the vines are not very healthy and the yield is low.

GRASSES

Brome grass, Kentucky blue grass, Australian rye grass, orchard grass, and other similar cultivated grasses so common in the Central and Eastern states are seriously injured or killed outright by our hot, dry summers at altitudes below 3000 feet. They make good growth, however, during nearly all of the fall, winter, and spring seasons. Seeds of such grasses should be sown in September or early in October when the maximum temperatures are considerably lower than in summer. During June and July the seeds of these

grasses will not germinate, ordinarily, even though given abundant irrigation.

Johnson grass and Bermuda grass are considered by farmers to be the two chief weed pests of the region. Both are dormant in winter, but grow vigorously throughout the summer. Bermuda grass is a fair lawn grass and presents a good appearance during the heat of summer when blue grass is either dead or in very poor condition. A good combination for lawns for the warmer valleys of the State is Bermuda grass and Australian rye grass, the former for summer growing and the latter for winter and spring. Australian rye grass is an annual under our climatic conditions, and is sown thickly and raked into Bermuda grass sod in September. With abundant irrigation it germinates readily and soon forms a velvety carpet which should be mowed during the winter and spring months. In early summer the rye grass dies out and is gradually replaced by Bermuda grass.

White clover is used to some extent for lawn purposes. It endures a wide range of temperatures since it grows both in summer, when it requires abundant and heavy irrigation, and in winter. Like blue grass it grows best in partly shaded lawns at altitudes below 2500 feet. Above altitudes of 3000 feet both these lawn plants grow well with most ordinary care. *Lippia nodiflora*, a member of the Verbena family, also grows well at lower altitudes for lawn purposes. This is a low trailing plant with an abundance of small, whitish flowers resembling those of the white clover. It will grow with less water than most other lawn plants and thrives in shallow soils that contain considerable broken caliche. It does best with moderate irrigation and should be cut with a lawn mower the same as lawn grasses.

Rhodes grass and Sudan grass have been introduced recently and are very promising as forage crops. Rhodes grass is believed to be native to southern Africa and is injured with winter temperatures of 5° F. or lower. It spreads from its roots by means of stolons which grow above ground and in a single season it usually forms a continuous tuft. There is no danger of its becoming a pest like Johnson grass since with one plowing it can be eradicated. It has not been grown in rich alluvial soils, but in ordinary mesa soil on the University grounds it has outyielded alfalfa several times, and with the most ordinary care makes a growth from early spring until late fall. Its heaviest growth appears to be made in July and August.

Sudan grass very much resembles Johnson grass. It is an annual plant, however, and has no rootstocks or underground stems of any kind. Its yields are heavy and where it has been grown as a crop it has given satisfactory results. The forage is rather coarse though much relished by stock. It grows best during the hot summer weather and is quite drought resistant. During the summer of 1913, the yields of this plant at the Experiment Station Farm at Phoenix were at the rate of 8 tons per acre from two cuttings. It also produces heavy crops of seed. This is desirable since the plant has to be sown annually.

GUAVAS

These tropical fruits are too sensitive to cold to be grown even in the warmest parts of the State. The common guava requires some protection during our mildest winters. The strawberry guava is somewhat hardier, but even this can not be grown satisfactorily in the Salt and Lower Colorado River valleys. One should not plant out fruits as tender as the guava unless he is well prepared to care for them in winter.

KAFIR AND EGYPTIAN CORN

(*See under Grain Sorghums*)

KOWLIANG

(*See under Grain Sorghums*)

LEMONS

The climate of Arizona is not as well suited to the culture of lemons as to oranges. The lemon is more tender, and to produce continually, as a commercial crop should, requires an equable climate near the coast. In a very few places in the Salt River and Yuma valleys, where the mercury does not drop below 25° F., the lemon can be grown for local consumption. In these valleys it will not produce fruit in summer when the fruit is in greatest demand.

Orchards should be heated when the temperature drops below 28° F. It is customary to start the heaters when the temperature gets a degree or two below freezing if it gets this cold before 12 or 1 o'clock a. m. The mercury generally falls until about 4 a. m. on a still night. It is easier to keep the temperature of the trees at

a given point by heating early than it is to raise the temperature after it has once fallen. Trees for home use should be planted in a protected place near buildings or other trees. The Eureka is the best market variety, but Villa Franca, Lisbon, and Sicily are good producers.

LETTUCE

Head lettuce is destined to become a commercial truck crop in Southern Arizona. It thrives in an arid climate if plenty of irrigating water is available. The quality of the crop can not be surpassed when the right variety is grown.

The growing conditions necessary for the production of lettuce are a cool growing season, ranging from not over 85° F. to not less than 20°; a rich, easily worked soil which will promote rapid growth; early thinning of the plants; frequent cultivation; and adequate irrigation, especially in warm weather.

In the southern part of the State seed should be sown in place any time from September to January. The plants should be thinned to 12 inches as soon as they have three or four leaves Delay in this checks the growth and increases the cost of the work. In cultivation, care should be exercised not to throw soil into the heads. A sandy soil is objectionable because the sand blows into the heads. Head lettuce can be had in the subtropical portions of the State from Thanksgiving until April. In cooler locations it is grown as an early spring crop. Hot weather causes lettuce to stop growing, become bitter, and send up a seed stalk.

The varieties which succeed best are those with the crinkled leaves. New York or Los Angeles, Iceberg and Denver Market are of this type, named in the order of their popularity. The smooth-leaved lettuces, like Big Boston, Tennis Ball, Salamander, etc., are so much inferior in this climate to the other varieties named that it is not advisable to grow them. Cos or Romaine lettuce and varieties of loose-leaf lettuce also grow well, but are not to be compared with either New York or Iceberg.

LOQUATS

Loquats are easily grown in the valleys in the southern parts of the State, below altitudes of 2500 feet. They bloom from November to January and, ordinarily, the flowers are killed by frost.

These trees are among the finest broad-leaf evergreens and are handsome ornamentals. When planted against a house or in protected situations the flowers and fruits are much less likely to be injured with frost, so that occasionally a good crop of fruit is produced. During the winter of 1912–1913 the foliage of loquats was not injured with a temperature of 6° F. Loquats are tolerant to our extreme heat and aridity, the foliage showing almost no bad effects in summer.

MILLET

Most varieties of millet can be grown readily, although the yield is not as great as in some cooler regions. The ordinary varieties are sown during August and harvested during the fall, as in other regions. German millet is most generally grown, being resistant to heat and drought. Pearl millet may be planted in the spring and will grow luxuriantly all summer, but does not seem as desirable for a forage crop as sorghum.

MILO MAIZE

(See under Grain Sorghums)

MULBERRIES

Mulberries are easily grown here, nearly all varieties thriving under our conditions. They are among the earliest of our trees to leaf out and to ripen fruit. Mulberries would be very desirable for shade trees were it not for the litter made by their fruit falling on the ground. This attracts flies and is annoying underfoot. Nurserymen are now propagating mulberries that are said to produce only staminate flowers. Such trees would be especially valuable for avenue planting. The heavy fruiting mulberry trees are valuable for planting in poultry yards because of their dense shade and spreading branches among which poultry may roost. Hogs are also fond of mulberries. The most desirable varieties for planting are the Downing Everbearing, New American White, Russian, and Persian or black mulberry. The Downing Everbearing mulberry has large long-pointed leaves that are dull green on the upper side. It is a form of *Morus multicaulis*. The New American is a form of the white mulberry. Its leaves are glossy above, large, and short-pointed. The Russian mulberry is a very hardy form of the white mulberry, usually having deeply cut leaves. It does not grow as large as the white mulberry, but

is hardy and is highly recommended for planting under dry farming conditions. The Persian mulberry branches from near the ground with stout, spreading limbs. The leaves are large and dull green. The fruits are broad and slightly hairy. When ripe they are black, juicy and tart, and are excellent for table use.

MUSKMELONS (CANTALOUPES)

The two terms are often used interchangeably, since there is no real distinction between them. In the West it is customary to call the small, round, netted melon the cantaloupe, and the large, oblong or flattened, netted or smooth melons, muskmelons. Both types are grown in the same way, the cantaloupe being far more popular than the muskmelon.

The cantaloupe or muskmelon requires a rich loam soil, preferably a sod soil, for its best development, a warm growing season, plenty of water, dry air, and plenty of sunshine during the ripening period.

The seed is planted as soon as danger of frost is over, the hills being placed about 4 to 6 feet apart with 8 to 12 seed placed in a hill along the water line of furrows to insure prompt germination. As soon as danger of insect damage to the seedlings is past, the plants are thinned to 2 or 3 in a hill. If the ground is foul with weeds or Bermuda grass the hills should be checked and cultivated in both directions. As the vines begin to run, the irrigation furrows should be moved away from the rows. The crop reaches maturity in from 80 to 120 days, depending on the weather and the variety.

Plantings of cantaloupes made in July in the southern part of the State are profitable if the aphids or plant lice do not take the crop. These lice are very difficult to control and are nearly always present. Tobacco spray, if thoroughly applied every week before the lice appear, will generally keep them in subjection.

The most popular varieties are Rockyford, Burrell's Gem, Nutmeg, Early Waters and Early Hackensack.

OATS

(*See under Grains*)

OLIVES

Olives are peculiarly well adapted to southern Arizona conditions. They are never injured by our summer heat and very

rarely is the fruit injured by cold. On account of the bright sunlight and dryness of the atmosphere, the trees are free from the scale insects which cause so much damage in moister climates. The trees grow vigorously, bear heavily, the fruit is large and the content of oil is high. Some varieties mature their fruit in October and November, while others will hold their fruit in good condition for oil making until June of the following year. Olive culture, both for pickles and oil, promises to be one of the standard and profitable industries of the region. The varieties best suited for pickles are Mission, Manzanillo, and Sevillano. The varieties best suited for oil making are Mission, Correggiola, Nevadillo, Pendulina, and others.

ONIONS

This crop is easily grown in southern Arizona as a winter crop, and in northern Arizona as a spring and summer crop. It is a profitable truck crop in most sections of the State, although prices may drop below the cost of production in June when growers are endeavoring to dispose of their entire crop at once. Bermuda, the type of onion best suited to this region, is not a good keeper, although when carefully handled and cured on racks in a house where sulphur may be burned, it will usually keep until fall. The cool valleys in the northern part of the State should produce onions for southern markets from fall until June. The supply at present comes from California.

The method of growing generally employed in the southern part of the State, is to sow the seed in seed-beds between August and October, and when the plants are the size of a lead pencil transplant into narrow borders which can be flooded. They are set 2 to 4 inches apart in rows 12 to 14 inches apart. With efficient management the cost of growing the plants and transplanting them need not exceed $35 per acre. Some growers prefer to sow the seed in place, planting two rows on a ridge. To avoid thinning with this method, an accurate knowledge of the viability of the seed and a careful adjustment of the seeder is necessary.

Growers in the northern valleys who wish to raise onions by the transplanting method, should arrange with a gardener in the Salt River Valley to grow their plants out of doors. Otherwise they should be grown in hotbeds, which is a more expensive method. A good loam soil, preferably enriched with rotted manure, well leveled, cultivated with a wheel hoe at frequent intervals, and irrigated as required, are essential to a successful crop.

Crystal Wax, White Bermuda, Yellow and Red Bermuda, and Australian Brown are the most popular varieties. Australian Brown is the best keeper, but it is not a sure crop in the warmest valleys. Yellow Danvers is successfully grown in the cool sections.

ORANGES

While oranges are being grown to an increasing extent on the upper slopes of the Salt River Valley, on the mesa near Yuma, and in some other localities, the area in Arizona where their culture may be profitably engaged in is quite limited when compared with the total of cultivated land. Orange trees being semitropical evergreens are severely injured when the mercury falls to 20°, and 16° will often kill the trees to the ground. The intense heat of summer is also very apt to injure the trunks unless the trees are headed low and properly pruned. For these reasons orange culture requires more skill and is attended with somewhat greater expense than in other orange growing localities. The incentive to grow oranges in a commercial way under these conditions is the high price received in the eastern markets for the Washington Navel variety, which ripens its fruit somewhat in advance of the California crop.

Partly on account of the hot dry climate citrus trees are not at present infested with scale insects. The chief insect enemies of the orange are several species of thrips of which *Euthrips tritici* is by far the most common. They distort the foliage and scar the fruit with considerable detriment to its selling value. Washington Navel is perhaps the most profitable variety. Valencia, Ruby, St. Michaels, Jaffa, and Mediterranean Sweet are also grown.

PEACHES

The different varieties of peaches differ considerably in their relation to the climatic conditions of the region. Some varieties escape injury from frosts most seasons and endure well the heat of summer. These varieties belong mostly to the Chinese type of peaches, blooming so early during the winter that the young fruit has attained sufficient size to endure quite low temperatures. As a result they set full of fruit every year. Other varieties not only receive considerable injury from spring frosts, but do not endure well the heat of summer. Peach trees are longer lived than apple or plum trees, but not so long-lived as either apricots or almonds,

usually remaining productive ten or twelve years from time of setting.

On account of the prevalence of spring frosts peaches are a very uncertain crop in exposed situations in the mountains. Some varieties of peaches are seriously injured by thrips which attack the winter buds just as they are unfolding in the spring. Those varieties which ripen their crop in the middle of the heated season suffer seriously from the *Allorhina* beetle. Ripe peaches are also very difficult to handle and market during very hot weather. The chief disease of the peach in Arizona is the crown gall of the roots which often does very serious damage (See Ariz. Sta. Bull. 33). Very few peaches are dried in the region for the same reason as given under "Figs." A very large list of peaches does well in the southern valleys, among which the following have been found to be especially desirable: Admiral Dewey, Alexander, Briggs May, Late Crawford, Elberta, Salway, Wheatland, Sylphide Cling, Krummel, St. John and Belle of Georgia.

PEANUTS

Peanuts may be grown in the lower irrigated valleys. They should be planted as soon as danger of frost is over; and mature five or six months after planting. They do best in sandy soils, require frequent irrigation and should be harvested as soon as yellow vines indicate maturity, to avoid sprouting the crop. The Spanish variety yields a heavy crop of small nuts. Virginia Red produces well if sufficiently irrigated. Indian Runner yields under less favorable conditions than Virginia Red. In addition to their uses as human food, peanuts make excellent hay. Being leguminous in character, the crop is beneficial to the soils upon which it is grown.

PEARS

Pears are well suited to all parts of Arizona, except in the very frosty mountain sections. They thrive in a heavy soil, bloom late compared with the stone fruits, and so usually escape damage by frost. On account of late blooming the pear can be planted in valleys where other fruits are less certain, and where the pear finds soil conditions better than on uplands where the soil is lighter.

The fire blight, which is so destructive in practically all pear-growing sections, is not so severe in our arid climate as it is in humid sections. Nevertheless, it can do very severe damage in this State,

especially in overfertilized or overirrigated soil. The blight attacks new, fast-growing tissue, and works down into the tree, causing cankers. No spray will check it. Every effort should be made to induce a stocky, conservative growth. The pruning out of infected parts below the infection is of very doubtful benefit, unless a section is in a position to enforce a rigid inspection of every pear tree in the agricultural district. There are few examples where this has been done with success.

There is only one pear in Arizona that will not blight. That is the Prickly Pear. Kieffer and Garber are less susceptible than varieties of French origin, but the quality of these Chinese pears is so poor that they are not grown unless the blight is very bad. The Bartlett is the most popular commercial variety. Other good varieties are Madeleine, Clapp's Favorite, Le Conte, Winter Nelis, and Patrick Barry.

PEAS

Peas are produced in abundance in the gardens of Arizona during the cool part of the year. They will stand temperatures of 22° to 25° without serious injury if they are not growing very rapidly. Heavy frost will kill the blossoms of most varieties. In the Yuma Valley it is warm enough for peas to bear most of the winter, but in most parts of the State they can be grown either as a fall or as a spring crop. Some of the hardier smooth peas may be carried over winter without being damaged.

The best time to grow peas in any part of the State is as a very early spring crop, planting being done between January 1 (or earlier) and April 15, according to locality.

Deep planting, 3 to 5 inches, is advisable, especially in the early fall, when peas rot badly if near the surface. Planting of dwarf varieties in double rows 10 to 12 inches apart, or in broad rows of 8 to 10 inches, allows the vines to support themselves, making cultivation and picking easier. The standard varieties are little grown because of the trouble and expense of supporting the vines.

PECANS

A few pecan trees are being cultivated in the Verde, Salt River, and Lower Colorado valleys. They thrive best in deep, rich soils with an abundance of irrigation. With proper culture they should grow successfully at altitudes of 5000 to 6000 feet. They seem to

endure well the summer heat in the lower valleys. The culture of pecans will probably never be successful commercially in Arizona, but it will be possible to grow them as ornamental and shade trees and to produce nuts of good quality for family use. The most suitable varieties of pecans for our conditions are Texas Prolific or Sovereign, San Saba, Colorado, and Frotscher.

PERSIMMONS

The common American persimmon (*Diospyros virginiana*) occasionally may be found under cultivation in the southern parts of the State. It withstands our summer heat very well if planted in deep alluvial soil and given moderate irrigation. It should thrive even better in the northern parts of Arizona where conditions of temperature are more nearly like those of its native habitat. The culture of Japanese persimmons has not yet gone far enough to justify planting them on an extensive scale. The individual trees scattered about the State seem to succeed well, but as yet they have not borne fruits.

PLUMS

At a very few situations in the mountains of Arizona nearly all varieties of plums succeed. In the hot southern valleys only certain kinds are profitable. These embrace certain varieties of the American and Japanese classes. A few of the European varieties will endure the summers for a few years and produce a fairly good quality of fruit, but most of them are short-lived. While prunes may be grown, they are not profitable on a commercial scale in the southern valleys.

Plums are injured much more by the heat of summer than by the spring frosts, the buds, blossoms, or young fruit rarely being injured seriously by frost. The only season during the past ten years when much injury was done was March 13, 1901, when the mercury fell to 32° in the government shelter, and 37° at the Weather Bureau. The various varieties of plums endure the summer conditions quite differently, the European varieties being most sensitive to heat. Those enduring heat best belong to the Japanese group, and most of those belonging to the American group endure summer fairly well. Unless the trees are headed low, the trunks are apt to be injured on the south and southwest sides, the trees dying later. The life of plum trees varies with the variety, that of desirable ones ranging from eight to twelve years. Plums are also subject to the

crown gall disease, though to a less extent than almonds and peaches. Some varieties, especially the American, are greatly injured by thrips which damage the winter buds to such an extent that the trees leaf out late and many of the branches die. Varieties especially suited to the hot valleys are Red June, Doris, Mariana (for jelly), Burbanks Chalco, Climax, and Wickson.

POMEGRANATES

All varieties of pomegranates are especially suited to the hot dry climate of the southern valleys. They are not injured either by the cold of winter or the heat of summer. Although they require irrigating water to enable them to bear profitable crops, well-established plants will remain alive and make some growth for many years with no other water than the natural rainfall. They are especially resistant to alkali and, all things taken into consideration, pomegranates are one of the surest crops of the region. The pomegranate is subject to but two serious troubles—a core rot and a splitting of the fruit, neither of which is at present well understood. On account of the fact that this fruit is but little known in northern markets, the demand is at present small, only a few orchards being in existence. Pomegranates are grown commonly throughout the southern part of the State as hedges, and shrubs for garden and lawn. Considerable fruit gathered from hedges is utilized by the Mexican portion of the local population. While all the varieties succeed admirably, the Wonderful excels all that have been so far tested, in size, beauty, and quality.

POMELOS (GRAPE FRUIT)

Districts which can produce oranges can produce pomelos. There is no radical difference between the culture of these two trees. The quarantine in Arizona and California on all citrus fruits from the Gulf States should give an impetus to pomelo culture in Arizona, since the quality of the Arizona fruit is superior to that of California. In fact, the best fruit produced at Yuma is little, if any, lower in quality than the Florida product.

The training and pruning of the pomelo consists in retaining only the strong branches of young trees which have been "headed" at approximately 3 feet when set out. Interfering and dead branches are removed and the growth of watersprouts is discouraged.

The best variety at present grown is the Marsh or Marsh's Seedless. It is probable that the poor quality of much of the western fruit is due, in a large measure, to the necessity of growing varieties poorly adapted to our conditions. Arantium, Duncan, and Triumph are sometimes grown.

POTATOES

But a very small proportion of the Irish potatoes consumed in Arizona is produced within the State. This is due to the fact that except at a few specially favored localities in the mountains, where irrigating water is available, potatoes are grown with considerable difficulty. While not easily grown in the hot southern valleys, they do moderately well when the methods that it is essential to follow for their successful culture are understood. Being sensitive both to the frosts of winter and the heat of summer, they can be grown only during late winter and early spring, and during the fall. For the spring crop they are planted during the latter part of January or the early part of February, and mature about the first of June. For a fall crop they are planted during the latter part of August or the first few days of September. The fall crop does not always fully mature before the frosts of November, but usually furnishes a limited supply of young potatoes for the table. The following additional remarks apply especially to the Salt River and Colorado River valleys.

With the exception of possibly a month in summer and about two months during winter, potatoes will germinate with more or less promptness after being planted in fairly moist soil. The usual planting season here is from the middle of January to the middle of February. Tubers planted during January send up sprouts nearly as rapidly as those planted later, but the young plants are apt to be injured by frosts. Potatoes planted December 23, 1899, and January 17, 1900, came up during February and were slightly injured by frost that occurred February 24, when the mercury fell to 26° at the ground, 29° in the government shelter, and 37° at the Weather Bureau, no injurious frosts occurring during March of that year. Potatoes planted January 9 and February 1, 1901, were slightly injured March 13, when the minimum temperatures were 27 at the ground, 32° in the government shelter, and 37 at the Weather Bureau. They continued growing until March 25, when those planted in January had reached a height of six to eight inches and those planted February 1, a height of two to four inches. Upon

the above date the larger ones were nearly all killed to the ground, and the smaller ones considerably injured, the mercury falling to 26° at the ground, 30° in the government shelter, and 35° at the Weather Bureau. Potatoes that were planted February 22, and were just coming up, were very slightly injured.

During five years' observations potatoes planted during February have received no serious injury from frost, although some plants have been slightly injured each year. During April, potatoes that started in February or early March grow rapidly and early varieties begin forming tubers. Thrifty growth continues throughout most of May, if no unusually warm weather occurs. In 1902 an unseasonably warm period occurred between May 6 and 10, the maximum temperatures being 108° to 110° at the soil each day, and 99° in the government shelter, and the mean relative humidity but 20. Potatoes planted January 20 and February 4 that were blossoming were considerably injured, and the crop was much lighter that year than usual. Some injury was also done May 12 and 13, 1903, when the maximum temperatures in the government shelter were 102° and 106°, respectively.

The increasing heat and aridity of June hasten the maturity or death of all potato tops, regardless of when they were planted or what the variety may be. Only early varieties have sufficient time to come to maturity before being overcome by the heat. The varieties that are grown most successfully in the region are Early Rose, Triumph, and Burpee's Extra Early. These varieties usually mature about the middle of June, although a large share of the crop is often dug and marketed considerably earlier than this. On account of the weather, the tubers deteriorate rapidly after ripening, whether dug or left in the ground. For this reason, by July 4 all the crop of the season is ordinarily consumed, except a small amount that a few growers save as best they can for summer planting.

From seed saved from the spring crop, a few potatoes are grown during autumn. They are planted during August or early September, and as a precaution against decay, are not cut. The sprouts sent up are usually distinctly slender and the subsequent growth is of the same character. As the cooler weather of autumn comes, they grow somewhat more rapidly, and produce a small crop of tubers. They do not usually have time for full maturity before the frosts of late autumn. In 1899 they were partly killed December 2, when the ground minimum temperature was 26°, in the government shelter 32°, and at the weather Bureau 38°, and were entirely killed

December 10, the minimum temperatures being 22° at the ground, 29° in the government shelter, and 34° at the Weather Bureau. During 1903, they were killed December 4, when the minimum temperatures were respectively, 25°, 34°, and 40° at the above points.

As the heat causes the keeping of potatoes through the summer to be very difficult, the saving of a portion of the spring crop for seed for planting the next winter is not attempted; and as the fall crop is both very light and insufficiently matured, none of it is ordinarily used for seed about Phoenix. Nearly all the seed used for winter planting comes from the Pacific coast. Attempts have been made at the farm to preserve seed from season to season, but without satisfactory results. Attempts have also been made to interest growers in neighboring mountain valleys to produce seed for the warmer valleys, but the local demand near the former is so great that these attempts have met with no better success. The impracticability of preserving seed for succeeding plantings interferes materially with experiments with this crop, and renders the planting of varieties not grown near the region expensive.

PUMPKINS AND SQUASH

There is very little difference between the squash and the pumpkin. Pumpkin is the name given to the golden-yellow, flattened, ribbed types of the same species to which the summer squash belongs. The stem of the pumpkin has no enlargement where it joins the fruit, but many types of squash have.

The bush squashes do well in the southern districts planted in the spring after danger of killing frosts. To take the place of the Hubbard squash, which does not thrive in the warm districts, the Cashaw should be grown, June or July being the best time for planting.

In cool sections the Hubbard squash can and should be grown to a greater extent, as there is good demand for it in our markets. Pike's Peak is a good squash of the Hubbard type. Squash can be grown as a farming crop.

QUINCES

Quinces succeed in all parts of the State when provided with sufficient water. They are never injured by the cold of winter and it is very rare that their blossoms are killed by spring frosts. They withstand admirably the heat of summer in the southern valleys provided they are headed low and so pruned as to provide shade

for the trunk. Quinces are especially resistant to alkali, but are susceptible to codling moth to the same degree as pears and apples. Were a market available, such as a jelly factory, large areas of quinces might be grown at a good profit. While all varieties do well, those which have done especially well at the Station Farm are Champion, Orange, Smyrna, Rea's Mammoth, and Meech's Prolific.

RADISHES

Radishes are easily grown during our cool season. The plant will stand considerable frost. The red, turnip-shaped varieties grow quickly but do not stay in good condition as long as the long white radishes. If people would accept white radishes they would find them of much better quality than the short, red kinds,and there is more quantity to them. White Icicle is probably the best quality of radish that grows. White Strausburg is another good long white variety, which stands the heat better than most radishes. Early scarlet Turnip is a good red variety. Winter radishes are grown and stored like turnips.

RASPBERRIES

Raspberries produce well only in the cool mountain valleys. The red varieties are propagated by suckers, while the blacks are propagated by tip layers. When the canes get "snaky" the tips are inserted in moist soil, where they root by fall. With the red varieties it is a problem to keep the canes from becoming too numerous, and with both varieties the old canes should be removed after fruiting, since a cane bears only once.

The loganberry, which resembles the raspberry and the blackberry, succeeds a little better in the warm parts of the State, but is not a good yielder. Cuthbert is the most popular red raspberry, and Gregg is the most popular black.

RHUBARB

Rhubarb is a perennial plant which survives our hot summers in the southern part of the State with great difficulty; but at the higher elevations, especially in the northern sections, it thrives and makes an excellent spring vegetable.

The culture of rhubarb is similar to that of asparagus. Either seeds or plants are set out 4 by 4 feet, in very rich soil, fertilized with generous amounts of stable manure. The first year or two is used to develop a good, strong, vigorous plant, which can stand having its leaves removed. There is little choice in the few varieties offered.

SHADE AND ORNAMENTAL TREES FOR PLANTING IN ARIZONA

Deciduous and evergreen trees listed below will succeed ordinarily in those sections of the State which fall within the altitude limits given, the (X) indicating successful growth. These altitude limits are necessarily arbitrary and have been chosen for convenience. A few of the tender evergreen species will be injured with extraordinary freezes at the uppermost limits named, and a few of the high mountain evergreen species may be found to grow with cultivation at altitudes lower than those suggseted. For further information concerning resistance of our cultivated trees to frost and for detailed information relative to the cultivation of these trees, see Timely Hints for Farmers, Nos. 62, 68, 79, 83, and 91.

DECIDUOUS SPECIES	Altitude limits		
	150-2500 ft.	2500-5000 ft.	5000-7000 ft.
Tree of heaven (*Ailanthus glandulosa*)	X	X	X
White mulberry (*Morus alba*)	X	X	X
Russian mulberry (*Morus alba tartarica*)	X	X	X
Teas' weeping mulberry (*Morus alba* var.)	X	X	X
Honey locust (*Gleditscia triacanthos*)	X	X	X
Arizona walnut (*Juglans major*)	X	X	X
Osage orange; Bois d'arc (*Toxylon pomifera*)	X	X	X
Weeping willow (*Salix babylonica*)	X	X	X
Arizona ash (*Fraxinus attenuata*)	X	X	.....
Umbrella tree (*Melia azedarach*)	X	X	.....
Valley cottonwood (*Populus MacDougali*)	X	X	.....
Arizona mesquite (*Prosopis velutina*)	X	X	.....
Soapberry; Wild China berry (*Sapindus Drummondii*)	X	X	.....
Plumose tamarisk (*Tamarix juniperina*)	X	X	.....
Native box elder (*Acer interior*)	.....	X	X
Western hackberry (*Celtis occidentalis*)	.....	X	X
Arizona sycamore (*Platanus Wrightii*)	.....	X	X
Black locust (*Robinia Pseudacacia*)	.....	X	X
American elm (*Ulmus americana*)	.....	X	X
English elm (*Ulmus campestris*)	.....	X	X
Russian oleaster (*Elaeagnus angustifolia* var.)	.....	X	X
Lombardy poplar (*Populus nigra italica*)	.....	X	X
Carolina poplar (*Populus deltoidea*)	.....	X	X
Western cottonwood (*Populus occidentalis*)	.....	X	X
White or silver poplar (*Populus alba*)	.....	X	X
Bolley's poplar (*Populus alba* var. *Bolleyana*)	.....	X	X
Black cottonwood (*Populus acuminata*)	.....	X	X
American persimmon (*Diospyros virginiana*)	.....	X	X
Kentucky coffee tree (*Gymnocladus dioica*)	.....	.....	X
Native canyon ash (*Fraxinus velutina*)	.....	.....	X

EVERGREEN SPECIES	Altitude limits		
	150-2400 ft.	5000-4500 ft.	5000-7000 ft.
Italian cypress (*Cupressus sempervirens*)	X	X	.....
Arizona cypress (*Cupressus arizonica*)	.....	X	X
Oriental arbor vitae (*Thuja orientalis*)	X	X	.....
Blue elderberry tree (*Sambucus caerulea*)	X	X	.....
Indian cedar (*Cedrus deodara*)	.....	X	X
Nut pine (*Pinus edulis*)	.....	X	X
Mexican nut pine (*Pinus cembroides*)	.....	X	X
One-seeded juniper (*Juniperus monosperma*)	.....	X	X
Alligator-bark juniper (*Juniperus pachyphlaea*)	.....	X	X
Rocky Mountain cedar (*Juniperus scopulorum*)	.....	X	X
Western arbor vitae (*Thuja occidentalis*)	.....	X	X
Silver fir (*Abies concolor*)	.....	.....	X
Cork bark fir (*Abies arizonica*)	.....	.....	X
Douglas spruce (*Pseudotsuga mucronata*)	.....	.....	X
Western yellow pine (*Pinus scopulorum*)	.....	.....	X
Arizonayellow pine (*Pinus arizonica*)	.....	.....	X
Colorado blue spruce (*Picea pungens*)	.....	.....	X
Engelmann spruce (*Picea Engelmanni*)	.....	.....	X
Australian beefwood (*Casuarina Cunninghamiana*)	X	.....	.....
Bitter or Seville orange (*Citrus aurantium vulgaris*)	X	.....	.....
Guadalupe cypress (*Cupressus guadalupensis*)	X	.....	.....
Monterey cypress (*Cupressus macrocarpa*)	X	.....	.....
Desert gum (*Eucalyptus rudis*)	X	.....	.....
Red gum (*Eucalyptus rostrata*)	X	.....	.....
Gray gum (*Eucalyptus tereticornis*)	X	.....	.....
Red box (*Eucalyptus polyanthema*)	X	.....	.....
Narrow leaf iron bark (*Eucalyptus crebra*)	X	.....	.....
California fan palm (*Neowashingtonia filifera*)	X	.....	.....
Common olive (*Olea Europea*)	X	.....	.....
Bagote (*Parkinsonia aculeata*)	X	.....	.....
Canary palm (*Phoenix canariensis*)	X	.....	.....
Date palm (*Phoenix dactylifera*)	X	.....	.....
Japanese loquat (*Eriobotrys japonica*)	X	.....	.....
Carolina palmetto (*Sabal palmetto*)	X	.....	.....
Ironwood (*Olneya tesota*)	X	.....	.....
Blue palo verde(*Cercidium Torreyana*)	X	.....	.....
Chinese windmill palm (*Chamaerops excelsa*)	X	.....	.....
Pepper tree (*Schinus molle*)	X	.....	.....
Australian bottle tree (*Sterculia diversifolia*)	X	.....	.....

SHALLU

(See under Grain Sorghums)

SORGHUM

Sown at any time from April to the end of July, Club-head and Amber sorghums usually give a heavy yield of fodder. The sac-

charine sorghums, also, when planted in rows and cultivated produce a fair quality of syrup. Forage sorghums are quite easily cured in this climate, but are often fed as they stand in the field. The season during which their seed will germinate begins during March, and continues until November. Seed does not germinate promptly but the young plants grow thriftily until April of most years. Little is gained by planting before the daily maximum temperatures rise to 85° or 90° F., and the minimum temperatures are over 45°. They are uninjured by the warmest summer weather, when they ordinarily make their best growth. They are all killed when the mercury falls below 30° F., this usually occurring during November. A good crop may be secured ordinarily by planting any time from April to July. If the moisture supply is sufficient under dry farming, the earlier planting is best; if it is not present sufficiently to bring the crops up, the later planting is to be recommended, for the summer rains usually begin then and will carry the crop to maturity.

SPINACH

Spinach is the most popular plant grown for greens. It grows with ease during the cool season if given enough water and a rich soil. Mr. James Phillips, a market gardener at Globe, reports that the best way to grow spinach under irrigation is to sow it broadcast in level borders and irrigate by flooding. The crowding causes the plants to grow upright, which makes bunching much easier. The soil must be very rich and free from weeds if this method is successful.

Prickly, Winter and Bloomsdale are the popular varieties.

SQUASHES

Squashes can be grown quite readily in Arizona if suitable varieties are used and they are planted at the right time of the year. Squashes are less sensitive to cold than melons and will germinate earlier in the spring. The bush varieties will start during February, and the remaining varieties will start nearly as early. As soon as the frosts that usually occur in March cease, growth becomes more rapid and continues until the hot weather of June. The bush varieties come to maturity at this time and cease producing squashes. The running varieties continue growing some longer, but growth is seriously interfered with if not stopped entirely, by the heat of midsummer. The bush varieties have ample time to produce a fairly

heavy crop, but few of the standard running kinds produce sufficiently well to justify their culture. These running varieties do best if planted during June or early July. The plants start well during the weather of these months, continue growing through summer, and produce a crop during autumn. The bush varieties will start during July and August and produce squashes during autumn, but do not grow as thriftily as during spring.

STRAWBERRIES

The strawberry is native to many of the high mountain regions of Arizona. While improved varieties may be grown in such localities with comparative ease, their culture becomes more and more difficult with decrease in altitude, and in the hot dry valleys in the southern part of the State it requires considerable skill to manage the crop successfully. Consequently those who have this skill usually secure a high percentage of profit from strawberry culture, due to the very high prices obtainable.

The greatest difficulty is carrying the newly set plants through the first summer. After becoming thoroughly established they do fairly well. The first good crop that can be counted on if the plants survive the first summer is during the spring of the second year after planting.

Like alfalfa, strawberries, being perennials, are exposed to the climatic conditions throughout the year. Unlike alfalfa, however, they are very shallow-rooted, resembling in this respect the perennial grasses. Strawberries are less sensitive to cold than alfalfa, but are more sensitive to heat, resembling in this respect also the perennial grasses. The vegetative parts of none of the varieties of strawberries are entirely killed by any low temperatures that occur in the region, and some of them produce some fruit throughout the coldest weather. On the other hand, all varieties are more or less injured by the heat of summer, only a few varieties withstanding the summer conditions, and a large percentage of the varieties succumbing entirely to the heat of midsummer.

The varieties that have been experimented with most extensively and which seem the most promising ones for the region, are Arizona Everbearing, Michel's Early, Excelsior, Texas, and Lady Thompson. The first variety mentioned has been grown in the region for many years, and is claimed to have originated near Phoenix. The second variety named has been grown here nearly as long, and is now more extensively planted than any other. The

last three named are newer varieties, and have been tested only a few years in the valley, mostly at the Station Farm.

The period during which strawberry plants will grow if transplanted extends from the latter part of October to the first of April, the month of February being the one during which they are transplanted with the best success. During the fall months, while it is possible to get most varieties to make a start, in many cases they die during the latter part of fall or early winter. If transplanted during the cold weather of December and early January, while they will not start to grow for some time, the most of them will eventually make a good growth. Those set during the latter part of January and during February usually start to grow promptly, and their growth is continuous until the hottest weather of summer. Those set after February start to grow promptly, but usually do not get sufficiently established before the hot weather of summer. Of the varieties mentioned, Michel's Early makes the poorest growth if transplanted during the fall, and Excelsior usually the best. Texas and Everbearing also make a fairly satisfactory start if transplanted during the fall.

Michel's Early, set November 2, 1901, and supplied with plenty of water, died within two weeks, and most of those set December 6 of the same year died within a month. Michel's Early set November 24, 1902, made a much better start and grew fairly well the next spring. Plants of this variety set November 6, 1903, made a very poor start and have not since grown satisfactorily, while plants set December 2 became better established.

Arizona Everbearing, set March 12, 1900, started well, and grew continuously until the hot weather of summer. Those not mulched with straw all succumbed to the heat, while three-fourths of those mulched with straw survived. Those set February 16, 1901, grew well until the hot weather of summer, but few plants survived the trying conditions of July and August. Plants of this variety set October 27, 1901, did not make a good start; those set November 24 of that year started better, but a large percentage died before the end of winter. Those set February 12, 1902, started well and grew continuously until injured by the heat of August, only a small percentage surviving the summer.

Excelsior plants set December 2, 1901, started well, grew through most of the winter, and made excellent growth until the hottest weather of the following summer, when a large percentage of them succumbed to the heat. Only a small percentage of the plants of this variety set October 27, 1902, made a good start, and some of

those set November 24 of that year failed to start. Those that became established lived through the winter, grew well the following spring, and survived the heat of summer well. Excelsior plants set February 15, 1903, started promptly, grew vigorously throughout the spring, few of them dying until the early part of August. During this month about 75 per cent of them succumbed to the heat. Plants of this variety set upon several dates during October of the season of 1903, started quite well and made a fairly good growth during the fall. Plants set November 6 and December 1 started and became quite well established.

Lady Thompson plants set December 2, 1901, started fairly well, but did not become established and survive the winter well. The majority of the plants of this variety set October 27, 1902, failed to start, but the majority of those set November 27 of that year became well established, made a good growth the following spring, and survived the following summer quite well.

Only a small percentage of Texas plants set October 27, 1902, started and became established, but nearly all those set November 24 of that year became well established, made good growth the following spring, and survived well the heat of the summer of 1903. Plants of this variety set February 16, 1903, started well, became well established, and made excellent growth until the hot weather of August. During the latter month a few of them succumbed to the heat, but most of them resumed growth when the cooler weather of September came.

The plants of the different varieties mentioned produce fruit at quite different times of the year in this region. The fruiting period of the Arizona Everbearing is usually during April, May, and June. While a few berries may be produced later in the summer than mentioned, and a few are sometimes produced during autumn, the amount is not sufficiently large to be marketed. The fruiting period of the Michel is of about the same length, but begins some earlier in the spring, extending from about the middle of March to the first of June. The Excelsior begins blooming during Oct ober ripens some fruit early in November, produces a considerable quantity by the end of November, and, if the weather is not too cold, produces a fair crop during December. Some fruit continues to ripen throughout the coldest weather of winter, during March begins ripening in greater abundance, and continues to ripen throughout spring until about the first of June. The Texas behaves similarly in this climate. It does not produce as much fruit during the winter but produces more during spring, the season during which

it produces most abundantly extending from the first of April to the first of June. The fruiting season of the Lady Thompson is a little earlier than the Everbearing and not quite so early as that of Michel or Excelsior, being much the same as that of Texas.

The blossoms are injured by temperatures below 30° at the ground, but the young fruit endures temperatures as low as 24°at the ground and 28° in the government shelter without injury; and green fruit protected by the foliage endures temperatures several degrees below this. The ripening fruit endures less cold, being injured by temperatures below 25° at the ground. A good picking was taken from Excelsior plants December 24, 1903, although the mercury had fallen at the ground to from 22°to 26°during ten nights of the month. Some green fruits well protected with foliage survived January, 1904, the mercury falling to 14° at the ground one night, 16° one night, 17° two nights, 18° one night, and 19° three nights; and a few berries ripened during the early part of the month.

SUDAN GRASS

Sudan grass belongs to the nonsaccharine sorghums and is well adapted to Arizona conditions. It is very resistant to drought and makes a very valuable forage crop for dry-farming. It responds to moisture and can be grown luxuriantly in the irrigated valleys of the State.

Sudan grass is closely related to Johnson grass. In fact, it is difficult to distinguish one from the other without examining the root system. Sudan has no underground stems and is an annual. It will not become a weed pest as Johnson grass does in the irrigated sections.

Sudan grass seed should be sown in the spring, as early as frost will allow. Under dry farming, if the moisture is insufficient for spring planting, planting should be done in July after the summer rains begin.

Sudan can be planted in rows and cultivated like other grain sorghums, or sown broadcast. When planted in rows, under dry farming, seeding should be at the rate of 4 to 6 pounds per acre. Broadcasted or drilled seed under irrigation should be at the rate of 16 to 25 pounds per acre. It is best to plant in rows under dry-farming conditions. Sudan grass is limited in its growth by cold weather. Hot weather is favorable to its best development.

SWEET CLOVER

Sweet clover can be grown in all parts of the State, but will be a better economic crop for the dry-farming districts. Where irrigation water is abundant alfalfa will prove far more profitable.

The variety best adapted to forage production is the yellow sweet clover. This is a biennial and should not be confused with the annual, *Melilotus indica*, a common variety growing in many parts of the State as a weed pest under the name of "sour clover."

Sweet clover should be sown in October or November on a well prepared seed bed. It may be sown, like alfalfa, from September to May. The best results, however, will be obtained by the fall sowing. Especially is this true in the dry-farming sections, where moisture conditions are more favorable at that time.

Sweet clover, being a biennial, can be cut for hay the first season, and harvested for the seed crop the second, after which it dies. Sweet clover should be cut higher than alfalfa, as the new growth comes from the axils of the lower branches, and not from a surface crown.

SWEET POTATOES

Sweet potatoes may be grown in southern Arizona at altitudes of less than 4500 feet, where water is available. They should be started in a hotbed in February, and the slips transplanted to the field as soon as danger of frost is over. Sweet potatoes do best in well fertilized sandy soils, and should be frequently irrigated. They require a long growing season and the yield steadily increases until frost. No serious pests have been observed, and experience has shown the crop to be sure and profitable. The Large White and the Georgia Yam are juicy sweet varieties producing heavily. The White Vineless is an excellent market variety. Yellow Jersey, Southern Queen, Shanghai, and Nansemond have also produced satisfactorily.

TOBACCO

This crop has not been tested thoroughly at the Station Farm, or elsewhere in the region, but the indications are that it may be grown successfully. A fair crop was secured the one season it was tested, and a fairly good product obtained.

It can only be grown where irrigation is ample. The seed should be sown early in a good cold frame where the little plants may be tended carefully. As soon as all danger of frost is past the plants may be transplanted to the field.

TOMATOES

Like potatoes, tomatoes are sensitive to both heat and cold' though not quite as sensitive to either. Tomatoes differ from pota-

toes in living through the summer and producing two crops on the same vines instead of requiring replanting.

Tomatoes are propagated in two ways in this region: (1) By planting the seed in the usual way in protected seed-boxes and either transplanting directly from these to the field or first transplanting to other boxes or to pots, and (2) by planting the seed in hills where the plants are to remain. As the latter method is the one that has proven preferable at the Farm, and as it is in following this method only that the seed and plants are exposed to outdoor conditions from the first, it is the one that will be discussed most fully. The principal advantages of planting the seed in hills outdoors are that this method involves less labor, and usually results in the production of an earlier and heavier crop. Though the seed may be sown much earlier in protected seed-boxes than outdoors, the transplanting of the plants under our climatic conditions usually so checks their growth and renders them susceptible to disease that they are surpassed in growth and production by those planted in the field.

Tomato seed will germinate outdoors and the young plants start and make continuous growth during most years from the middle of February to the first of May. In 1899, seed planted in January did not send up many plants until the end of February, but they grew continuously thereafter, tomatoes maturing earlier than on plants grown from seed planted in boxes January 3 and transplanted April 10. Some seasons the young plants receive some injury from frosts, but as a rule few young plants are killed, enduring a surprising amount of cold if planted in the field. During the spring of 1900 the young plants from seed planted out February 10 were not injured by cold. In 1901, about a fourth of the young plants from seed planted February 14 were killed March 25, the minimum temperature being 26° at the ground, 30° in the government shelter, and 35° at the Weather Bureau. They had been uninjured by a previous frost March 13 when the minimum temperatures were 27° at the ground, 32° in the government shelter, and 37° at the Weather Bureau. In the spring of 1902, tomatoes growing from seed that had lain in the ground over winter were uninjured March 4, when the minimum temperatures were, respectively, 27°, 33°, and 38° at the above points; but were slightly injured March 26 when the minimum temperatures were 30°, 33°, and 36°, respectively, at the same points. During the spring of 1903 tomatoes were uninjured outdoors, though March 19 the mercury fell to 27° at the ground, 13° in the government shelter, and 36° at the Weather Bureau.

After the early part of April the weather is sufficiently warm for tomatoes to begin making more rapid growth, and until the first of June most varieties grow with increasing rapidity. As the weather grows warmer, only the varieties with heavy foliage continue thrifty. All varieties with finely divided or thin foliage are seriously injured by heat during June, and none of them produce much fruit. Only the Dwarf Champion, and a few related varieties with heavy foliage, can be counted on to produce a crop regularly.

Fruit begins ripening during the latter part of June and increases in quantity until the middle of July. The vines continue to make some growth and to ripen fruit until about the middle of August. While they continue blossoming some through the summer, no fruit is ordinarily set after the middle part of July. Hence, none ordinarily ripens during the latter part of August, or during September. As the weather becomes cooler during the latter month, fruit again begins to set. It begins ripening during the latter part of October, the total amount of the crop depending upon the earliness of the fall frosts. The vines are usually killed during the latter part of November or the early part of December. In 1899, they were killed December 10, and in 1900 not until December 27. In 1901 they were slightly injured December 8, when the minimum temperatures were 27° at the ground, 31° in the government shelter, and 36° at the Weather Bureau, and were nearly killed the next morning, when the minimum temperatures were, respectively, 25°, 28°, and 33° at these points. In 1902, they were slightly injured November 16, when the minimum temperatures were 31° at the ground, 35° in the government shelter, and 43° at the Weather Bureau, were considerably injured November 26, when the minimum temperatures were, respectively, 29°, 32°, and 34° at these points; were partially killed November 28, when the minimum temperatures were 27°, 30°, and 34°; and were killed December 3, when the mercury fell to 24°, 28°, and 33° at the above points. During 1903 they were killed December 5, when the record showed minimum temperatures of 25° at the ground, 30° in the government shelter, and 35° at the Weather Bureau.

By comparing the records of spring and fall frosts it will be seen that young tomato plants endure quite as low temperatures as mature ones, and in some cases were uninjured by lower temperatures than seriously injured full-grown vines. In the fall, fresh growth is usually injured less than older growth, indicating that more vigorous action on the part of the plant renders it less susceptible to the effects of frost.

Tomato Insects and Diseases.—The most serious disease which affects the tomato in this country is a wilt which may attack the plant in almost any stage. The sapwood of the plant is clogged near the ground, this being indicated by a tan colored area in the sapwood. The plant shows slight indications of disease until it wilts and dies. Little is known of this disease. Transplanted plants seem to be affected more than plants grown in place. The late-planted plants seem to be attacked less than early planted ones. Rotation may do some good, but there is no remedy known. Blight may attack the vines. This can be controlled by spraying the vines with Bordeaux mixture, made at the rate of 4 pounds of bluestone, 4 pounds of lime, and 50 gallons of water. This is a preventive, and not a cure for diseased vines.

Blossom end rot seems to be caused by an irregular water supply, but this is not proven.

Few insects trouble tomatoes. Cut worms may kill a good many young plants, but poison bran mash will control these. The "tomato worm," which attacks corn and cotton is widely distributed and may do damage. There is no satisfactory remedy.

TURNIPS

Turnips of all varieties are easily grown in almost any part of Arizona. In the mountains they are grown in the summer and in the hot southern valleys in the fall, winter and spring. The seed will germinate in the southern valleys at any time from August to the succeeding May, in most cases germinating quickly during the warmest weather of this period and slowly during the coolest. During both the warmest and the coldest weather also, the young plants are apt to be injured, though injury by cold is less frequent and less severe than injury by heat. Well established plants are not severely injured by cold.

All varieties do very well, including the rutabagas, which require a lower temperature for germination than turnips.

VELVET BEANS

Velvet beans, which are reported to grow so luxuriantly and to be so valuable as a forage and green-manuring crop in some portions of the South, have not thus far proved valuable for this region, the aridity of the atmosphere probably being too great for their successful culture.

WALNUTS

The Arizona walnut (*Juglans major*), native in canyons and river valleys in parts of Arizona, is grown to some extent as a shade and ornamental tree. It appears one of the hardiest and best adapted of all our deciduous trees. The Persian, or so-called English walnut, which is grown quite extensively in parts of California, succeeds well in valley soils in Arizona with abundant irrigation, when grafted on the native walnut stock. On its own roots, however, and usually on the roots of the California black walnut, the English walnut has not been a success. There is a number of fine large English walnut trees grafted on Arizona walnut stock in the Upper Gila Valley, some of which have borne regularly for 15 years or more. A few thrifty English walnut trees also are growing about Tucson. Mr. C. R. Biederman's work in grafting and growing French, German, and English walnuts has so much of promise for the future of the walnut industry in the Southwest that the Experiment Station was led to issue Bulletin No. 76, "Walnut Growing in Arizona." This describes in full Mr. Biederman's methods of grafting and discusses the possibilities of commercial walnut growing in Arizona. By virtue of their late blooming habits and dense foliage, French walnuts appear best adapted to our climatic conditions. Some of the more promising of these are the Franquette and the Marquette.

WATERMELONS

Watermelons of prime quality are easily grown at the lower altitudes and in the valleys throughout central and southern Arizona. The period during which melon seed germinates extends from March (the time in the month depending on the season) until October. Most of the early varieties germinate earlier in March than the later ones, the Augusta starting the earliest of any tested at the Farm, but no varieties make much growth until the mercury ceases to fall below freezing at the ground. Seed planted before the latter part of March germinates very slowly and during the early stages the young plants are sometimes injured by frost and usually show little promise of giving better results than those planted later; but the first planted are ordinarily the first to produce ripe melons. Those planted during the early part of April ordinarily grow without interruption by cold, but usually ripen their melons a week or so later than those planted in March. During the warm weather of May and June, while the maximum

temperatures range from 90° to 105°, growth is rapid, the first melons ripening usually at the Farm during the last week of the latter month, but occasionally as early as June 20.

If the vines are supplied with sufficient water, the melons produced are of prime quality until about the last of July, but from then on are apt to deteriorate, the early varieties first, and the later varieties later. By the middle of August the intense heat causes such early varieties as Augusta to be unfit for market, and a little later the Florida Favorite becomes affected by the heat. During the warm weather of August only the latest varieties or late-planted earlier varieties produce melons of good quality. If supplied with plenty of water the vines continue growth throughout the summer, and will produce melons of good quality during September and October, especially if they are cut back and the soil between the rows cultivated and refurrowed.

As seed germinates promptly, and young plants grow thriftily throughout the summer, plantings for the production of fall melons may be made during June and early July. The vines from seed planted at this time grow rapidly through August and September, producing ripe melons in abundance during the latter month. As the cooler weather of October comes, growth and ripening are very slow, and during November or the early part of December the vines are killed by frosts. In 1899 they were killed December 1, the minimum temperatures at the ground being 28°, in the government shelter 32°, and on the building of the Phoenix Weather Bureau, 39°. In 1900, with the occurrence of the above temperatures October 28, they were only partially killed, not being entirely killed until December 3, when the mercury fell to 28° at the ground, to 32° in the government shelter, and to 35° at the Weather Bureau. In 1901, they were not injured by frost until December 8 and 9, the mercury falling to 25° at the ground upon the latter date. In 1902, they were killed November 26 and 27, the minimum temperature the latter night being 27° at the ground. In 1903, they were not killed until December 4, the minimum temperature being 25° at the ground, 34° in the government shelter, and 40° at the Weather Bureau. This last record furnishes an illustration of the fact that plants may be injured or killed when the thermometer in the government shelter, 5 feet from the ground, does not register a freezing temperature, and when the minimum temperature recorded at the Weather Bureau is many degrees above freezing.

The varieties best adapted to the southern valleys, as determined by extensive tests at the Station Farm are Augusta, Florida

Favorite, Sweetheart, Rattlesnake, Fordhook First, Blue Gem, and Kleckley Sweets. The Chilean is an excellent late variety.

WHEAT

(*See under Grains*)

RECAPITULATION

From the foregoing discussion of the leading crops of the region and the effects of the weather on them, it will be seen that a larger number endure the low temperatures that occur than endure well the high ones, a condition the opposite of that existing in the northern portion of the country. Instead of crops being grown between two winters, as is the case in the North, the most of them are grown between two summers, the number that grow through the summer here being about the same as live through the winter in the North.

Wheat, barley, oats, rye, peas, flax, canaigre, beets, alfalfa, clovers, lupins, vetches, cabbage, cauliflower, lettuce, spinach, carrots, turnips, radishes, onions, strawberries, olives, dates, oranges, lemons, pomelos, tangerines, loquats, and Eucalypts remain green throughout the winter, and make more or less growth. Of these the small grains, flax, canaigre, beets, clovers, cabbage, cauliflower, lettuce, spinach, carrots, turnips, radishes, onions, olives, and some species of Eucalypts are injured by the lower temperatures of winter.

Besides those that grow through winter, beans, Indian corn, potatoes, and bush squashes grow only between the coolest weather of winter and the hot weather of summer, these being, like those listed above, sensitive to heat, but also sensitive to extreme cold.

The crops keeping green through summer are the grain and forage sorghums, millet, cowpeas, peanuts, broom-corn, tobacco, cotton, alfalfa, tomatoes, melons, pumpkins, squashes, some varieties of beans, celery, strawberries, mulberries, persimmons, grapes, figs, plums, nectarines, peaches, apricots, almonds, apples, pears, quinces, walnuts, olives, dates, oranges, lemons, pomelos, pomegranates, loquats, cottonwoods, ashes, and Eucalypts.

Of the above, the following grow thriftily throughout the hot weather of midsummer: Grain and forage sorghums, cowpeas, tobacco, cotton, olives, dates, and some species of Eucalypts. Of these the date is the one that seems to enjoy the summer conditions best.

The crops liable to be injured by spring frosts are corn, potatoes, tomatoes, beans, grapes, peaches, apricots, almonds. The crops that

are usually injured by autumn frosts are corn, sorghums, beans, cowpeas, cotton, potatoes, and tomatoes. Those liable to injury by the low temperatures of winter are peas, alfalfa, lettuce, strawberries, dates, oranges, lemons, pomelos, and Eucalypts.

The crops that are killed or brought to maturity by the heat of summer are small grains, clovers, Indian corn, flax, bush beans, potatoes, summer squashes, cabbage, cauliflower, lettuce, spinach turnips, radishes, onions, rhubarb, raspberries, currants, and goose berries. In addition to the above the following are checked in their growth by the summer heat: Beets, alfalfa, tomatoes, melons, cucumbers, squashes, pumpkins, asparagus, strawberries, blackberries, deciduous fruits, citrus fruits, and Eucalypts.

WHAT MAY BE PLANTED AND WHAT MATURES EACH MONTH

Believing that information as to what may be planted each month with hope of success and what commonly matures each month in the Salt River Valley, will be of value, especially to new settlers, the following classified statement is inserted. In parts of southern Arizona having a cooler climate, planting is done later in the spring and earlier in the summer; and in the vicinity of the Colorado, planting takes place earlier in the winter and somewhat later in summer. In the first paragraph under each month is given the list of the crops that may be planted, and in the second paragraph those that mature or reach a stage suitable for use.

It will be seen from what follows that the time for planting the largest number of crops is during January, February, and September, and that the greatest number of crops mature during May, June, October, and November. During May and December comparatively few crops are planted, and January and February are the months during which comparatively few crops mature.

JANUARY

Planted: Wheat, barley, oats, alfalfa, peas, beets, potatoes, cabbage plants, carrots, lettuce, spinach, turnips, radishes, asparagus seed and roots, onion sets, strawberries, blackberries, grape cuttings and plants, deciduous fruit trees, date seed.

Mature: Cauliflower, lettuce, spinach, table beets, turnips, radishes, oranges, and pomelos.

FEBRUARY

Planted: Wheat, barley, alfalfa, Indian corn, peas, beets, tobacco, potatoes, tomato seed, bush squashes, lettuce, spinach, tur-

nips, radishes, onion sets, celery seed, asparagus plants, cabbage plants, strawberries, blackberries, deciduous fruit trees, citrus fruits, olives, date seed.

Mature: Cauliflower, cabbage, lettuce, spinach, table beets, turnips, radishes.

MARCH

Planted: Indian corn, grass seed, cotton, beans, peanuts, melons, cucumbers, squashes, pumpkins, citrus fruits, olives, Eucalypts.

Mature: Cauliflower, cabbage, lettuce, spinach, beets, turnips radishes, carrots, green onions, asparagus, strawberries.

APRIL

Planted: Grain sorghums and broom corn, grass seeds, cowpeas, peanuts, cotton, date plants, Eucalypts.

Mature: Grain hay, alfalfa, green peas, cabbage, lettuce, spinach, table beets, carrots, turnips, radishes, green onions, asparagus, strawberries, mulberries.

MAY

Planted: Grain sorghums and broom corn, cowpeas, date plants.

Mature: Wheat, barley, oats, alfalfa, table corn, peas, potatoes, bush squashes, string beans, cabbage, lettuce, table beets, carrots, turnips, asparagus, strawberries, blackberries, plums, apricots, peaches.

JUNE

Planted: Grain sorghums and broom corn, cowpeas, melons, squashes, pumpkins, date plants.

Mature: Alfalfa, Indian corn, potatoes, tomatoes, melons, cucumbers, bush squashes, beans, beets, carrots, onions, strawberries, blackberries, figs, plums, peaches, apricots, apples.

JULY

Planted: Indian corn and grain sorghums, millet, cowpeas, melons, squashes, pumpkins, date plants.

Mature: Cowpeas, sugar beets, alfalfa, tomatoes, melons, cucumbers, grapes, figs, plums, peaches, apples, pears.

AUGUST

Planted: Peas, beets, beans, cowpeas, millet, potatoes, cabbage and cauliflower seed, carrots, celery plants, cucumbers, lettuce Eucalypts.

Mature: Grain and forage sorghums, sugar beets, cowpeas, tomatoes, melons, grapes, figs, plums, peaches, apples, pears, almonds.

SEPTEMBER

Planted: Wheat, barley, oats, grass seeds, peas, beans, potatoes, beets, cabbage and cauliflower seed and plants, celery plants, lettuce, spinach, radishes, beets, carrots, turnips, onion seed.

Mature: Grain and forage sorghums and broom corn, cowpeas, peanuts, cotton, melons, grapes, plums, peaches, apples, pears, dates, pomegranates.

OCTOBER

Planted: Small grains, grass seeds, alfalfa, clovers, peas, beets, cabbage seed and plants, cauliflower plants, onion seed, carrots, radishes, turnips, lettuce, spinach.

Mature: Cowpeas, cotton, grain and forage sorghums and broom corn, millet, alfalfa, tomatoes, melons, cucumbers, squashes, pumpkins, string beans, peanuts, grapes, plums, peaches, apples, quinces, pears, dates, pomegranates.

NOVEMBER

Planted: Small grains, alfalfa, clovers, peas, cabbage plants, radishes, beets, turnips, lettuce, spinach, strawberries, date seed.

Mature: Grain and forage sorghums, cowpeas, alfalfa, potatoes, tomatoes, pumpkins, squashes, peas, beans, lettuce, spinach, table, beets, turnips, radishes, celery, strawberries, grapes, peaches, apples, pears, quinces, olives, dates, oranges, pomelos, pomegranates.

DECEMBER

Planted: Small grains, peas, radishes, strawberries, date seed.

Mature: Lettuce, spinach, table beets, turnips, radishes, celery, strawberries, apples, pears, olives, dates, oranges, pomelos.

WHEN EACH CROP MAY BE PLANTED AND WHEN IT MATURES

For the further convenience of those desiring information concerning the planting of crops, the proper time for planting each and the time when each usually matures in the vicinity of Phoenix, are given. Our seasons are so different from those in most portions

of the country that those unfamiliar with the region are naturally apt to become somewhat confused as to the proper time for planting the great variety of crops that can be grown in the region. The times given are those when experience has shown that each crop should be planted in order to secure the best results. The time of maturity given is that when each crop reaches the stage when it is most suitable for the use for which it was planted. In the case of many vegetables this is while the plant is still in a green immature state; and in the case of such a fruit as pears it is some time after, not only the cessation of growth on the part of the tree, but of the removal of the fruit itself.

ALFALFA

Planted: September 20 to November 10; January and February.
Mature: April 15 to August 15; October 15 to November 15.

ALMONDS

Planted: January and February.
Mature: July and August.

APPLES

Planted: January and February.
Mature: June 15 to December.

APRICOTS

Planted: January and February.
Mature: May 10 to June 20.

ASPARAGUS

Planted: January to March; October and November.
Mature: March and April of third year, and after.

BARLEY

Planted: September to March 1.
Mature: April and May.

BEANS

Planted: March and first half of April; August 15 to September 15.
Mature: May 15 to June 15; October 20 to November 15.

BEETS, TABLE

Planted: January to March 15; September and October.
Mature: January to July; October to December.

BEETS, SUGAR

Planted: January 15 to end of February; September 20 to October 10.
Mature: July and August; March.

BLACKBERRIES

Planted: January and February.
Mature: May and June of second year.

BROOM CORN

Planted: April to July.
Mature: September to November.

CABBAGE

Seed planted: August 15 to November.
Plants set: January and February; September 15 to October 20.
Mature: February to June.

CARROTS

Planted: January and February; August 20 to October 15.
Mature: January to July; November and December.

CAULIFLOWER

Seed planted: August and September.
Plants set: September and October.
Mature: January to April.

CELERY

Seeds planted: January to March.
Plants set: August 15 to October 15.
Mature: November and December.

CLOVER, "SOUR"

Planted: October 15 to November 20.
Mature: March.

CORN, EGYPTIAN

Planted: April 15 to July 15.
Mature: September and October.

CORN, INDIAN

Planted: February 20 to March 15; July 10 to August 5.
Mature: May 15 to June 15; October and November.

CORN, KAFIR

Planted: April, May, and June.
Mature: September and October.

COTTON

Planted: March and April.
Mature: September to December.

COWPEAS

Planted: April to August.
Mature: August to November.

CUCUMBERS

Planted: March and April; June and July.
Mature: June and July; September and October.

DATES

Seed planted: All seasons.
Plants set: April to August.
Fruit Mature: September to January.

EUCALYPTS

Seed planted: August to January.
Plants set: March, April, and August.

FETERITA

Planted: April to July.
Mature: July to October.

FIGS

Planted: January and February.
Mature: June and July.

GRAPES

Planted: January and February.
Mature: July 10 to December.

GRASSES

Brome, blue, and orchard grasses.

Planted: September to May.
Bermuda and Johnson grasses.
Planted: April to October.

LETTUCE

Planted: January, February, September, and October.
Mature: January to May.

MELONS

Planted: March and June.
Mature: June 20 to November.

MILLET

Planted: August.
Mature: October.

MILO MAIZE

Planted: April to July.
Mature: July to October.

OATS

Planted: October to December.
Mature: April and May.

OLIVES

Planted: February and March.
Mature: October to January.

ONIONS

Seed planted: September 15 to October 15.
Sets planted: November to February.
Green onions: February to April.
Mature: June and July.

ORANGES

Planted: February and March.
Mature: November to January.

PEACHES

Planted: January and February.
Mature: May 25 to November.

PEANUTS

Planted: March.
Mature: September and October.

PEARS

Planted: January and February.
Mature: July to January.

PEAS

Planted: January and February; August 20 to November 20.
Mature: April, May, and November.

PLUMS

Planted: January and February.
Mature: May 10 to October.

POMEGRANATES

Planted: January and February.
Mature: October and November.

POMELOS

Planted: February and March.
Mature: November to January.

POTATOES

Planted: January 15 to February 15; and August 20 to September 10.
Mature: May 20 to June 15; November.

PUMPKINS

Planted: March and June.
Mature: July and October.

QUINCES

Planted: January and February.
Mature: October.

RADISHES

Planted: January to March; August to October.
Mature: January to August; October to December.

SHALLU

Planted: April, May, June.
Mature. August to October.

SORGHUM

Planted: May and June.
Mature: September to November.

SPINACH

Planted: January, September, and October.
Mature: November to May.

SQUASHES

Planted: March, June, and August.
Mature: May, June, and October.

STRAWBERRIES

Planted: November 20 to February 20.
Mature: March to July; December.

SWEET POTATOES

Planted: March to May.
Mature: September to November.

TOMATOES

Planted: February and March.
Mature: June 20 to August, and October 20 to December.

TURNIPS

Planted: January, February, August, September, and October.
Mature: October to May.

WHEAT

Planted: September to March.
Mature: April to June.

In using the above tables due allowance in time should be made for other parts of the State than Salt River Valley, to which they particularly apply. In the Colorado Valley, near sea level, for instance, limiting temperatures both of heat and frost are two to four weeks earlier in the spring and about two weeks later in the fall. At higher elevations limiting temperatures occur correspondingly later in the spring and earlier in the fall.

University of Arizona
Agricultural Experiment Station

Bulletin No. 79

Plant of *Opuntia ficus indica* in the introduction garden, University Farm, badly injured with a temperature of 21 degrees F. The illustration shows 6 months growth since the freeze.

Cold-Resistance in Spineless Cacti

By J. C. Th. Uphof

INTRODUCTION

By J. J. Thornber

Tucson, Arizona, December 1, 1916

University of Arizona

Agricultural Experiment Station

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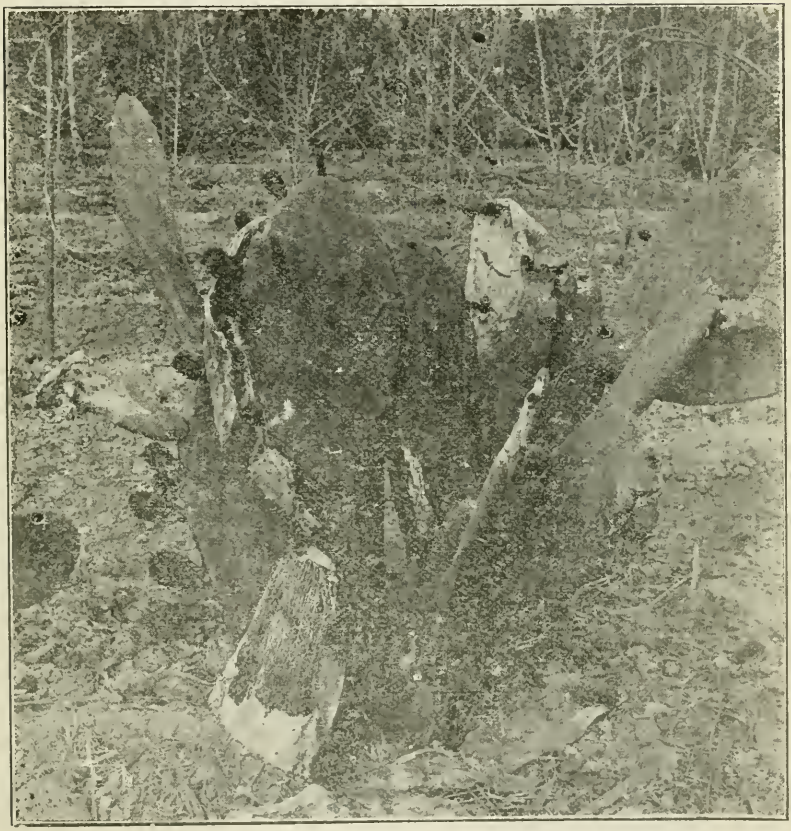

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INTRODUCTION

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Tucson, Arizona, December 1, 1916

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AGRICULTURAL EXPERIMENT STATION

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Visitors are cordially invited, and correspondence receives careful attention.

The Bulletins, Timely Hints, and Reports of this Station will be sent free to all who apply. Kindly notify us of errors or changes in address, and send in the names of your neighbors, especially recent arrivals, who may find our publications useful.

Address, THE EXPERIMENT STATION,
TUCSON, ARIZONA.

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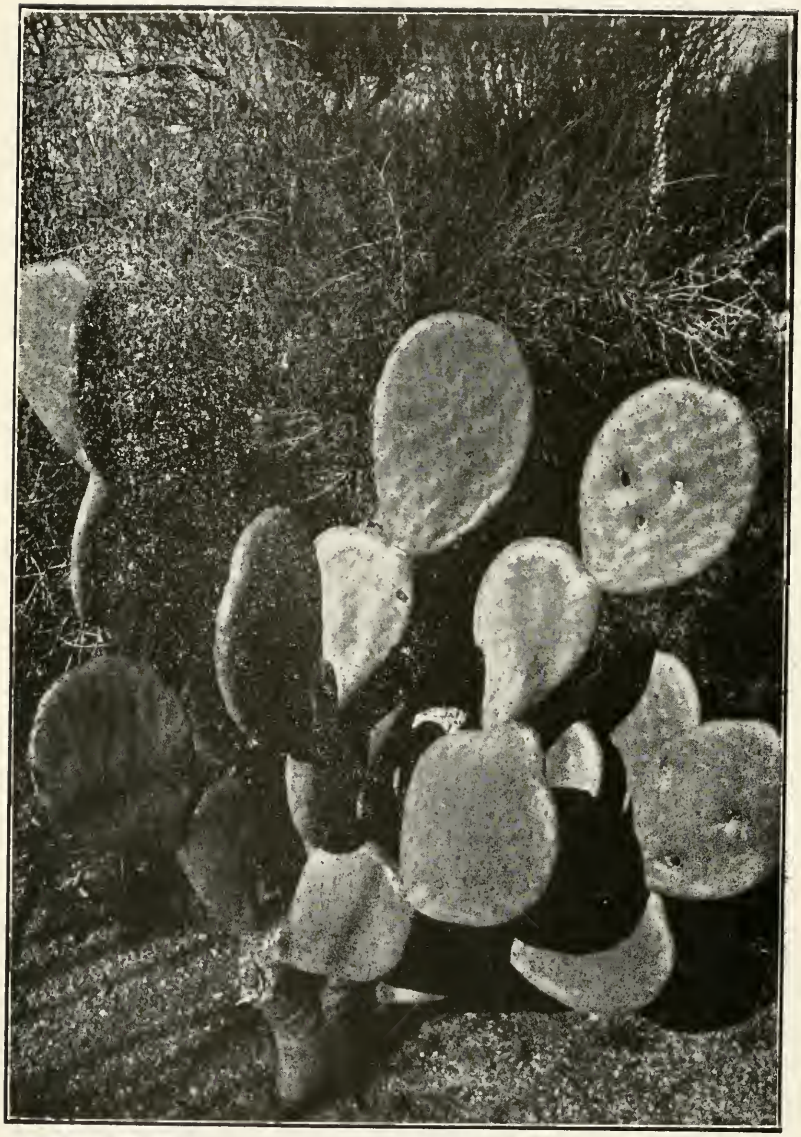

Plate I. Plant of *Opuntia Castillae* in the cactus garden, University grounds, uninjured with a temperature of 12 degrees F., but seriously frozen with a temperature of 6 degrees F.

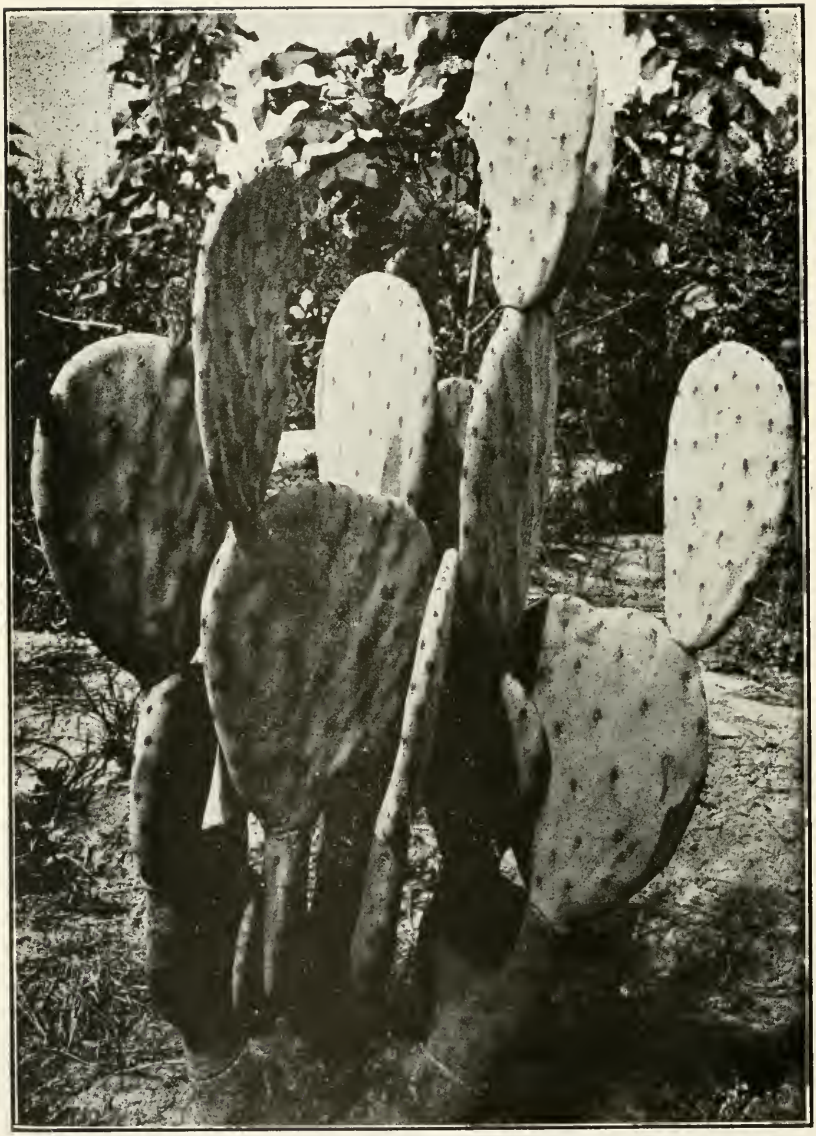

Plate II. Plant of *Opuntia* sp. Burbank Special in the introduction garden, University Farm, injured with temperature of 20 degrees F. Plant of rather rapid growth.

Cold Resistance in Spineless Cacti

INTRODUCTION

The differences in the frost resistance of cacti, the importance of these plants in parts of Arizona as emergency and supplemental stock feed, and the perennial interest in spineless cacti as possible forage plants, led to the outlining of this Adams fund project. This study has for its object the determination of the causes of hardiness in cacti and is designed to throw light on the question as to whether resistance to cold in these plants lies in the character and structure of the plant body or in the character of the cell sap and the protoplasm. An attempt has been made to determine the limits of resistance in several species and varieties of spineless cacti. These plants have been studied both in the field and in the laboratory with reference to the relation between their morphology and physiology and cold resistance. The behavior of their protoplasm at low temperatures has been carefully noted. No attempt has been made to determine the critical temperature which the plant can endure without injury to its tissues, but the minimum freezing temperature which has been found to damage the plant has been noted, also the temperature at which the plant is killed quickly. The results obtained in this study by Mr. Uphof check closely with field observations made by the writer on *Opuntia castillae* over a period of fifteen years.

This experiment was also suggested partly through the failure of Burbank spineless cacti to grow successfully under Arizona conditions and to endure our winters, as noted by the writer in Bulletin 67 of this Station. This observation, together with the fact that our State has a rich and varied cactus flora, led to numerous speculations concerning the factors of hardiness in cacti. Though this study has been outlined for some time, the laboratory work was begun by Mr. Uphof, in cooperation with the writer, only last summer. Recent studies in the native cacti of our State have led to the observation that the various species almost invariably have a limited altitudinal distribution. This means, in brief, that the different species are confined to areas similar in temperature and rainfall conditions. In a few instances low winter temperatures are known to be the chief factor in limiting the distribution of certain species, as, for example, *Cereus Thurberi*, the organ-pipe cactus, *Cereus giganteus*, the giant cactus, and *Cereus Schottii*. The explana-

tion underlying the distribution of the great number of our cacti, however, has not been made, although in the light of Mr. Uphof's experiments minimum winter temperatures are a factor. In this connection it will be interesting to observe that during the very cold winter of 1912–13 thousands of small giant cactus plants growing near their greatest altitudinal limits were killed outright. Many other species also suffered great damage.

For this study in hardiness, plants of spineless cacti—spineless *platopuntias*—were secured from various sources, and, together with those already growing on the University grounds, were set in the introduction garden at the University Farm, in the spring of 1914. The writer is under obligation to Fraser Bros., Wellton, Arizona, for a number of varieties of spineless cacti, including *Opuntia ficus indica*, from Sicily and Malta, and *Opuntia* sp. Burbank Special. The latter was thought to be a very hardy variety. Mr. B. R. Russell, San Saba, Texas, kindly furnished plants of *Opuntia Ellisiana*, which he calls the San Saba spineless pear. This latter species is entirely spineless and has shown itself hardier than any other variety of spineless cactus growing in the introduction garden. It is, however, slower growing than some other species. Other species represented were *Opuntia fusicaulis*, a slender jointed spineless pear, which the writer found in cultivation in Tucson gardens, and *Opuntia castillae*. These were recently described by Dr. Griffiths and are native to Mexico. *Opuntia castillae* is known to have been growing in Tucson in the gardens of various Spanish and Mexican residents for as long as thirty years and is commonly known as "nopal de castilla." Forms of it are entirely spineless, though the younger joints have a few fine spicules which sooner or later disappear. It is often seen in cultivation in parts of southern California, where it is occasionally used as a hedge plant. Under the most ordinary conditions it grows to a height of 6 to 10 feet, the trunks and older branches becoming quite stout with age. It is not injured by our highest summer temperatures, even with rather arid culture, though for good growth it should have a reasonable amount of soil moisture. It is well adapted for growing in southern Arizona, where the lowest winter temperatures do not fall below —12.2° or —11.1° C.(10° or 12° F.). In December,1901, it was not injured with a temperature of —12.2° C. (10°F.), extending over a few hours. In January, 1913, it was frozen back one-half, or more, on the University grounds, and also in Tucson with a temperature of —14.4° C. (6° F.). This latter temperature extended over a considerable portion of the night and was preceded by nearly

24 hours of almost continuous freezing weather. This is said to be the lowest temperature ever recorded for Tucson. At Phoenix, Arizona, this species was killed back about one-fourth to one-fifth during this same cold spell.

The soil in the introduction garden is deep and alluvial in character. It is a fine, sandy loam and has good drainage. Some black alkali is present, though apparently this has not injured the growth of these cactus plants in the least. The cuttings were planted on low ridges and cultivated and irrigated between the rows, all the plants being given the same care. The soil has been kept in good condition during the growing season of the plants. The various plants have made at best but a moderate growth, particularly when the favorable growing conditions are considered. *Opuntia castillae*, *Opuntia ficus indica*, *Opuntia fusicaulis*, and *Opuntia* sp. Burbank Special grew to heights of 14 to 24 inches during the first year with 4 to 8 joints each. Plants of *Opuntia Ellisiana* made growths of 10 to 12 inches with 2 to 5 joints each. As already noted, this is a slower growing species than the others, but very hardy. The winter of 1914–15 was milder than usual and little damage from frost was done to the matured growth of any but the tenderest species, viz., *Opuntia ficus indica*, *O. fusicaulis*, and *Opuntia* sp. Burbank Special. The lowest temperatures at the University grounds for the winter season were —4.4° C. (24° F.) on December 9, and —5.6° C. (22° F.) on the nights of December 15, 1914, and January 8, 1915, respectively. These temperatures were of short duration. *Opuntia Ellisiana* and *O. castillae* were not injured in the least, while *Opuntia fusicaulis*, *O. ficus indica*, and *Opuntia* sp. Burbank Special were only slightly injured. The greatest injury was done by the freeze of December 8, since up to that time the weather had been mild, and some of the plants were making considerable growth. Naturally, the tender immature joints were easily killed. Altogether, the plants came through the winter season in good shape and began a healthy growth in the spring of 1915.

It is interesting to observe that *Opuntia castillae* and *O. Ellisiana* ceased their growth by the middle of October, or the first of November at latest, even with favorable growing conditions. *Opuntia ficus indica*, *O. fusicaulis* and *Opuntia* sp. Burbank Special, on the other hand, continued growth ordinarily until freezing weather began in December. There may be some relation between hardiness in *Opuntia castillae* and *O Ellisiana* and their better adaptability to our climatic conditions. This, however, might account for hardiness

in these plants only so far as the first severe cold spell is concerned. The immature joints of these species which continue growth until a severe freeze, are naturally killed with the first heavy frost. However, the matured growth of *Opuntia ficus indica* and *Opuntia* sp. Burbank Special, which ceased their growth before freezing weather, showed no greater resistance to cold than the matured growth of plants that had made active growth until frost.

In concluding this statement it should be said that the laboratory work has been done entirely by Mr. Uphof, who is a Hollander by birth and training, and has resided in this country for but a few years. While he took very careful notes on his experiments, it was not possible for him, without help, to write up his results for publication. This fell to the lot of the undersigned, who has endeavored to state the results as Mr. Uphof understands them. Mr. Uphof has gone over this paper several times with the writer's help, and has made numerous suggestions to state more fully his ideas. With this brief statement, the writer asks that this work be regarded as Mr. Uphof's.

J. J. THORNBER.

HISTOLOGICAL STUDIES

GENERAL STRUCTURE OF THE OUTER, THICKENED PART OR INTEGUMENT OF A CACTUS STEM

It is quite difficult to make thin hand sections of living cacti and similar succulent plants, as the tissue is soft and often slimy and does not section readily. It was found that sections could be made for ordinary study with a hand microtome. In order to study the tissues from a histological or cytological standpoint, however, it was necessary to embed small pieces of the cactus in paraffin and make sections with a rotary microtome.

A histological study of certain parts of the cactus plant is very essential, as it is one of the means which may determine whether a certain species is hardy or not. The difference between the outer tissue layers of different species of cacti, especially those which are resistant to certain low temperatures, and those which are not, is very remarkable. In order to show these differences, joints of several species of Opuntia of different ages were selected.

I first made a study of the layers of tissue outside the woody bundles of a well developed two-year-old joint of *Opuntia castillae*. In studying a section of this under the microscope, the thick-membraned cells at the periphery, or outside, and the large thin-walled cells toward the center of the stem, or joint, were observed.

The first layer encountered is the epidermis; it can still be detected easily in stems which are three and even four years old. The epidermal cells of two-year-old stems sometimes contain protoplasm; however, this seems to be an exception in the plants which were worked with. The epidermis soon secretes a cuticle or secondary membrane, which after a few months becomes quite thick. When young this is stained light yellow with a concentrated solution of potassium hydroxid; older cuticles stain darker yellow, which suggests that the outside membrane of the epidermis is heavily saturated with suberin, the same substance which forms in cork. The stomata, or breathing pores, are small but numerous and are embedded in the cuticle.

Immediately below the epidermis follows a layer which we will call the "crystal-bearing layer," since its cells always bear crystals. Its outer and lateral membranes are thin, but the ones toward the

center of the plant are thick. Its cells are characterized by the presence of crystals of calcium oxalate; when young these are star-shaped, but with age they lose their beautiful stellar appearance and come to occupy practically the entire space in the cell. Later crystallization of these bodies through lack of space is very irregular. The calcium oxalate everywhere lies closely next the inner membrane of the cell and forms, with similar material of the neighboring cells of the same layer, a continuous crystallized wall under the epidermis.

The next layer of tissue is usually three to five cells thick and with age has very thick membranes, which also are suberized, though not so heavily as the cuticle. This layer is everywhere furnished with plasmodesmi (i. e., connections of protoplasm between different cells through the cell walls,) which are rather difficult to detect but which are shown beautifully under the microscope when the slides are immersed for a few minutes in each of the following solutions, in the order named:

1. 1 per cent osmic acid.
2. Potassium iodid in iodine.
3. 25 per cent sulphuric acid.

The sulphuric acid swells the membranes and shows the plasmodesmi clearly. The writer observed that tissues afterwards put for a moment in Delafield's haematoxylin until the membranes become light red sometimes show good results.

The tissue lying between the thick-celled layers, already described, and the woody part of the joint, is a large-celled parenchyma, or soft tissue. In comparison with the others its membranes are thin, and often show plasmodesmi, which can only be detected, however, with the already noted precautions. These cells are mucilaginous and contain several large chloroplasts or green bodies. Each of these chloroplasts contains, during sunny days, from 4 to 12 small starch grains. The cells toward the central part of the joint contain fewer chloroplasts and less of the mucilaginous matter, but, on the other hand, more water. Some cells of this parenchyma show star-shaped crystals of calcium oxalate somewhat similar to those already noted.

The origin of the different layers and cells of a stem, or joint, may be studied to best advantage in young joints. Here the epidermis appears as a tissue formed by the dermatogen,* while the cells of the crystal-bearing layer, the thick-celled layer, and adjacent large-celled parenchyma (all together forming the cortex)

* Dermatogen and periblem belong to the primary tissues of a growing stem.

lie, in an early stage, in a straight radial direction and take their origin from the periblem, which direction may be observed here and there in Fig. 1. At a later age it is impossible to find out how the tissues were formed, as the cells of the green parenchyma sometimes divide longitudinally, and the thick-walled cells are so crowded that they no longer lie inradial rows.

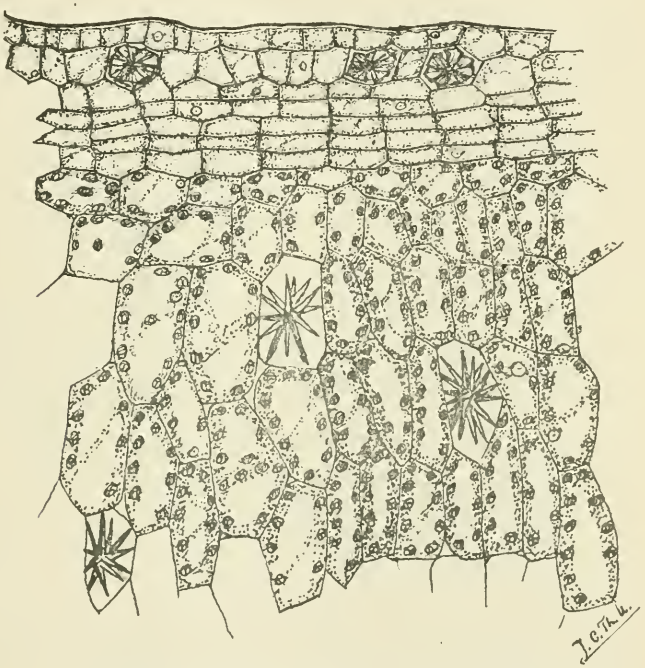

Fig. 1.—Cross-section of a piece of joint of *Opuntia castillae* about two weeks old, showing regular character of cells. (Highly magnified).

It is hardly necessary to mention that the thick cuticle, the crystal-bearing layer, and its adherent thick-celled tissues, together with the slimy contents of the green parenchyma, are of great importance to the plant, as these protect the stem against a high transpiration rate, which would be disastrous for the species in a dry and hot climate. It would not be worth while to describe the thickness of the layers of that part which forms the integument of the stem (i. e., cuticle, epidermis, crystal-bearing layer, and thick-celled layer) if it were not observed that this integument is thickest in those species which are resistant to cold. More than this, physiological experiments demonstrated that the time of penetration of a certain temperature varies greatly when integuments of different species of cacti are used.

It will be interesting, therefore, to describe the outside layers of each of the six species of cacti with which the writer worked.

STUDY OF RELATIVE THICKNESS OF CUTICLE, CRYSTAL-BEARING CELL LAYER AND THICK-WALLED CELLS OF DIFFERENT SPINELESS OPUNTIAS

1. *Opuntia castillae* has a cuticle 15 to 20 μ thick, the cells of the crystal-bearing layer are from 30 to 42 μ thick, and the following thick-celled layer is100 to 120 μ thick. Individuals from the University Farm, from the cactus garden on the campus of the University of Arizona, and from a garden in the vicinity of Tucson were obtained. These plants all showed the same general structure. In the writer's experiments, plants from the University Farm were used, as the other species which follow were also grown in the introduction garden at the University Farm under similar conditions. This species was damaged at a temperature of —14° C. (6.8° F.).

2. *O. ficus indica*, from Malta. This species shows, in comparison with the former, a cuticle 5 to 10 μ thick; the crystal-bearing layer is 30 to 38 μ thick, and the thick-celled layer is 55 to 75 μ. in thickness. This species is not hardy in the field and was injured at temperatures below —6° C. (21.2° F.) in the laboratory.

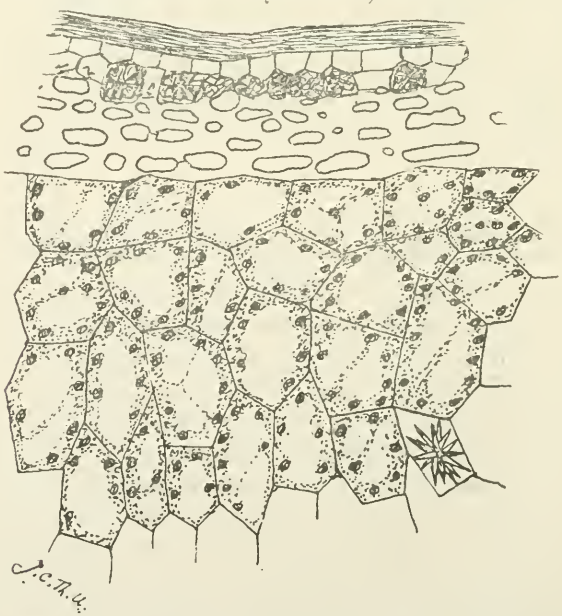

Fig. 2.—Cross-section of a piece of joint of *Opuntia castillae* about two years old. The integument is thick. (Highly magnified)

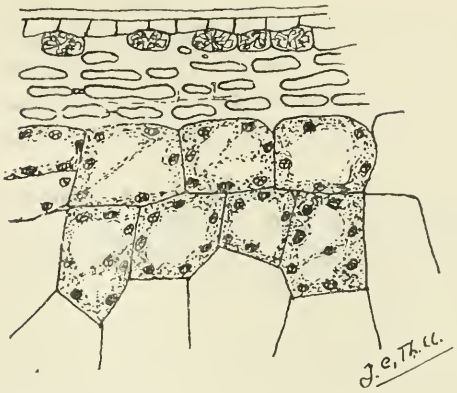

Fig. 3.—Cross-section of a piece of joint of *Opuntia* sp. Burbank Special, about two years old. Note the relatively thin integument. (Highly magnified).

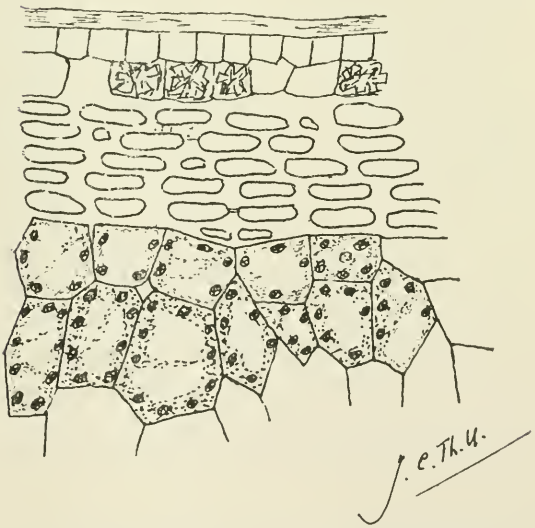

Fig. 4.—Cross-section of a piece of joint of *Opuntia Ellisiana* about two years old. Note the thick integument. (Highly maguified).

3. *Opuntia* sp. Burbank Special. The integument of this species is thin. The cuticle is 5 to 8 μ thick, the crystal-bearing layer 30 to 38 μ, and the thick-celled layer 70 to 87 μ. This species is not hardy and was killed at a temperature of —8° C. (17.6° F.).

4. *O. Ellisiana* has, like *O. castillae*, a thick cuticle of 12 to 15 μ, a crystal-bearing layer of 25 to 35 μ, and the next layer of 75 to 130 μ. This species is quite hardy; it is said to be resistant to tem-

peratures of —17° C. (1.4° F.). No direct observations, however, have been made in the field at this low temperature.

5. *O. fusicaulis* has a cuticle 10 to 12 μ thick, a crystal-bearing layer of 20 to 30 μ, and a thick-celled layer 87 to 98 μ. in thickness This species is not hardy. It is injured at a temperature of—6° C. (21° F.).

6. *O. ficus indica*, from Sicily, has a cuticle 12 to 15 μ thick, a crystal-bearing layer 30 to 40 μ, and a thick-celled layer 62 to 74 μ. in depth This species is not hardy; it is injured at temperatures below —5° C. (23° F.).

It will be observed that the cuticle and the thick-celled layer show great differences in thickness, while the crystal-bearing layer is more nearly of the same thickness throughout.

The table below gives a summary of the thickness of the various layers noted above.

SUMMARY OF THICKNESS OF CELL LAYERS IN CACTI

Name of plant	Thickness of cuticle	Thickness of crystal-bearing layer	Thickness of thick-celled layer
Opuntia castillae	15–20 μ	30–42 μ	100–120 μ
O. sp. Burbank Special	5– 8 μ	30–38 μ	70– 87 μ
O. ficus indica, from Malta	5–10 μ	30–38 μ	55– 75 μ
O. Ellisiana	12–15 μ	25–35 μ	75–130 μ
O. fusicaulis	10–12 μ	20–30 μ	87– 98 μ
O. ficus indica, from Sicily	12–15 μ	30–40 μ	62– 74 μ

RELATION OF PENETRATION OF TEMPERATURE TO THICKNESS OF INTEGUMENT OF CACTI

To determine whether the length of time of penetration of temperature is influenced by the thickness of the integument or not the following experiment was performed. Pieces of the integument about 5 by 5 cm. in extent were dissected from the joints of all of the above Opuntias. The integument of each species was wrapped carefully around the bulb of a thermometer and tied with a thin wire. Such prepared thermometers were put quickly in large test tubes the openings of which were closed with plugs of cotton. The test tubes had been in an ice box at a temperature of 4° C. (39.2° F.) several hours before the thermometers were placed in them. After the thermometers were inserted in the test tubes and the openings closed with cotton, the

latter were placed in a glass cylinder filled with crushed ice and salt. In this way a temperature of 0° C. (32° F.) was reached easily.

This experiment was repeated three times, and each time gave results showing that the rapidity of penetration of the cold is dependent upon the thickness of the integument.

Fig. 5.—Apparatus used for determining the rate of penetration of temperature through the integuments of various spineless cacti; and, also for making a comparative study of the cooling points, freezing points, and duration of freezing points of different spineless cacti.

On an average it took 63.3 minutes for the temperature to penetrate *Opuntia castillae* and 79.3 minutes for it to penetrate *O. Ellisiana*, both species of which have thick integuments. The length of time required for the other species was much shorter.

The following table gives a summary of the experiment, the number of minutes indicating the time required for the temperature to reach 0° C. (32° F.).

SUMMARY SHOWING TIME REQUIRED FOR A TEMPERATURE OF 0° C. TO PENETRATE DIFFERENT CACTI

Name of plant	First reading	Second reading	Third reading	Average
	Mins.	*Mins.*	*Mins.*	*Mins.*
Opuntia castillae	73	52	65	63.3
O. ficus indica, from Malta	31	39	35	35.0
O. Ellisiana	79	77	82	79.3
Opuntia sp. Burbank Special	37	33	28	32.6
O. fusicaulis	35	40	41	38.6
O. ficus indica, from Sicily	32	48	48	40.6

PHYSIOLOGICAL STUDIES

In order to ascertain why these plants were injured by cold it was necessary to consider four main problems:

1. Are the plants killed at a temperature a little above the freezing point of water, as is often the case with tender greenhouse plants?

2. Is the injury caused by the freezing of water in tissues of the plant body?

3. May the plant tissues be killed by poisoning caused by the cell sap becoming more and more concentrated, as its water gradually changes into ice?

4. May the protoplasm withstand only certain temperatures below 0° C. (32° F.) without injury, and after having exceeded that degree of cold, be killed?

EFFECTS OF TEMPERATURE AT THE MELTING POINT OF ICE ON THE TISSUES

Beginning with the first problem—stems and parts of stems of *Opuntia castillae*, *O. fusicaulis*, *O. Ellisiana*, *Opuntia* sp. Burbank Special, *O. ficus indica* from Malta and from Sicily were put in crushed ice in an ice box, where they remained for two days at a temperature of 0° C. (32° F.). After six hours the material was examined, but was not at all injured. After 48 hours the material was again examined, but none of the stems were killed or apparently injured. Parts of these cactus joints were then placed in a constant temperature oven at a temperature of 60° C. (140° F.) for six hours, at the end of which time they showed no apparent injury. It is evident, therefore, that these plants can endure a considerable range of temperature without injury. It is quite possible, however, that they might have been injured by this latter temperature had it been continued for a longer time.

Slides of tissue of cactus plants were put for different periods on ice, but the cells were not damaged. This suggests that the cells are not injured with the temperature of melting ice. The first problem is, therefore, disposed of.

Protoplasmic Movements

It is interesting to observe the movements of the protoplasm of the living cells of cactus stems under different temperatures. In studying a tissue at room temperature, which was about 29° C. (84.2° F.), the streaming of the protoplasm is noticeable through the rapid movements of the microsomes and physodes; the large chloroplasts also, and not infrequently the nucleus, are often seen to move for a short time. When the temperature is gradually lowered by putting ice around the slide, the protoplasmic movement becomes slower and slower until it finally stops. The location of the different protoplasmic structures and the size of the cells, however, remain the same; and the cells have not lost their turgor. After the ice has melted, the water around the slide soon takes the temperature of the surrounding air and the protoplasm in the cells again begins its movements.

DETERMINATION OF THE COOLING AND THE FREEZING POINTS IN CACTI

The second problem is very interesting and raises several additional questions. It takes into consideration the behavior of the plant at temperatures below the freezing point. The following experiment was performed in this connection. Pieces about 10 by 10 by 25 millimeters in size were cut from the stems of cactus plants. In the middle of these the bulb of a thermometer was inserted. The thermometer, with the piece of cactus in position, was next placed in a large test tube and the opening closed with a plug of cotton batting. This test tube was next placed in a mixture of ice and salt so that a temperature of —20° C. (—4° F.) was reached.

The thermometer soon dropped from the temperature of the cactus to —1° or —0.75° C. (30.2 or 30.6° F.) the cooling point, and then rose quickly to 0.25° to 0.50° C. (32.45° to 32.9° F.). After this the temperature remained for a considerable time at 0.50° to —1.50° C. (32.9° to 29.3° F.). This latter temperature is known as the freezing point and has a remarkably small variation with the different species of cacti that were studied. The length of time, however, during which this temperature is maintained by the different species of cacti varies considerably. After the temperature remains

at this freezing point for some time, as will be noted later, it drops fairly regularly to the temperature of the air in the test tube, which was kept usually at —20° C. (—4° F.).

COMPARISON OF COOLING POINTS, FREEZING POINTS, AND DURATION OF FREEZING POINTS IN DIFFERENT SPINELESS CACTI

1. *Opuntia castillae.*—The cooling point was reached at —1° C. (30.2° F.) and rose to —0.50° C. (31.1° F.), the so-called freezing point, where it remained from 35 to 44 minutes, when the temperature dropped for a while slowly, and afterwards rapidly, until —20°C. (—4° F.) was reached.

2. *O. ficus indica* from Malta.—The cooling point was reached at —.75° C. (30.65° F.). The temperature rose now quickly to —0.25° C. (31.55° F), the freezing point, where it remained from 12 to 18 minutes, then the temperature dropped quickly to —20° C (—4° F.).

3. *O. Ellisiana* reached its cooling point at —0.75° C. (30.65° F.) and then went up to —0.50° C. (31.1° F.). Afterward it remained at a temperature between —0.50° and —0.20° C. (31.1° and 31.64° F.) for about 20 to 28 minutes, when it began to drop rapidly.

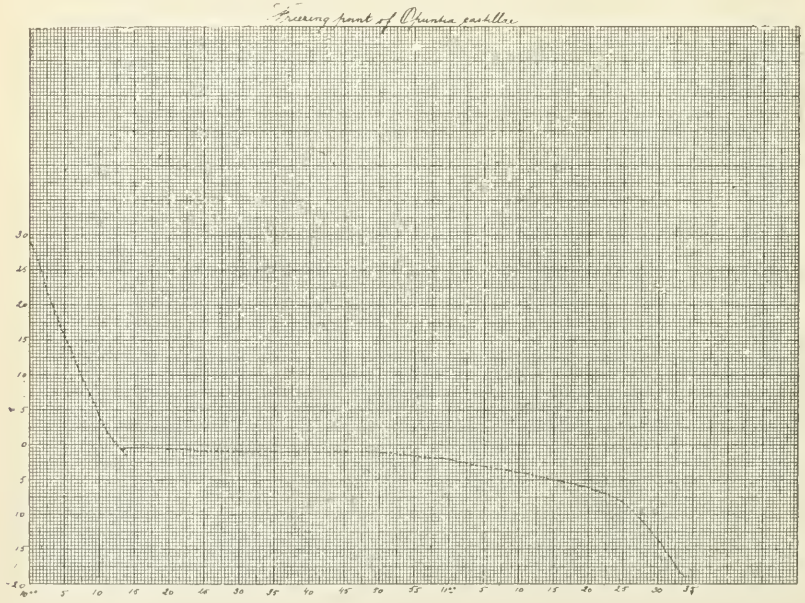

Fig. 6.—Curve showing cooling point, freezing point and duration of freezing point of *Opuntia castillae.*

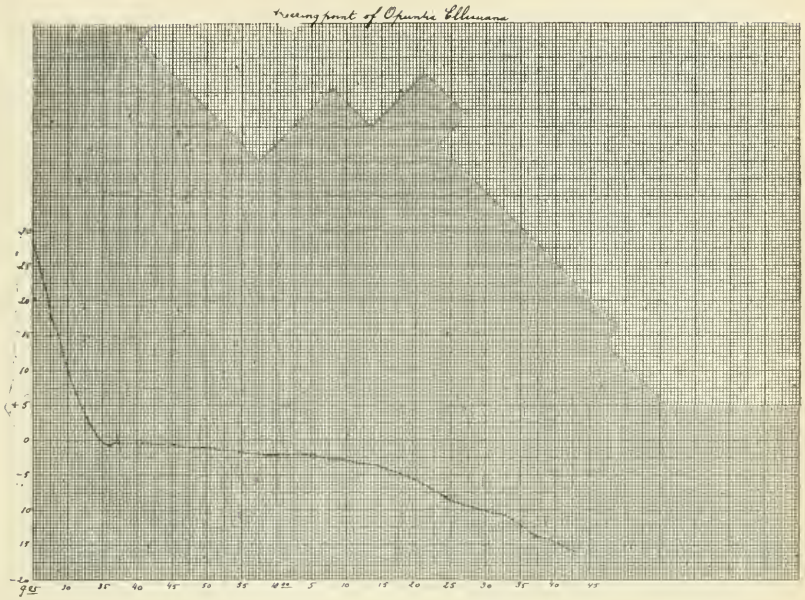

Fig. 7.—Curve showing cooling point, freezing point and duration of freezing point of *Opuntia Ellisiana*.

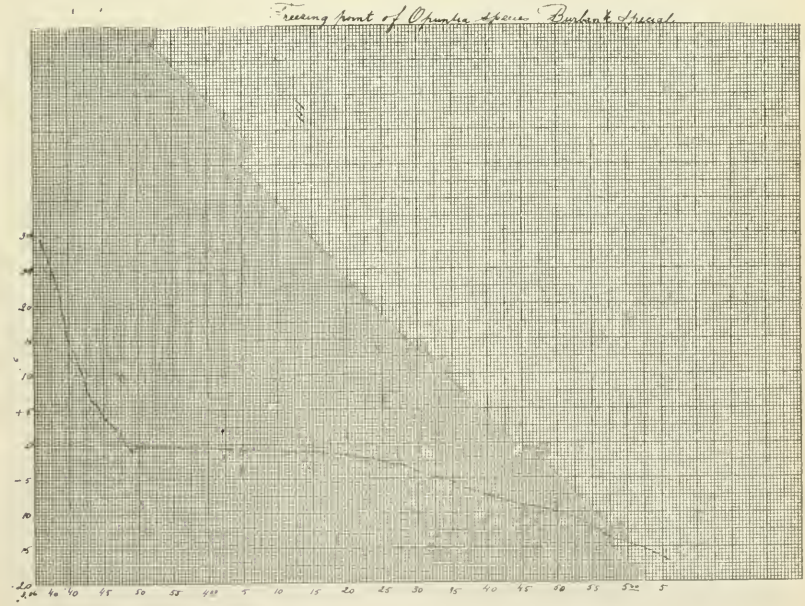

Fig. 8.—Curve showing cooling point, freezing point, and duration of freezing point of *Opuntia* sp. Burbank Special.

4. *Opuntia* sp. Burbank Special has a cooling point of —1° C. (30.2° F.) and a freezing point of —0.20° C. (31.64° F.),where it remained from 22 to 30 minutes and dropped afterwards rapidly.

5. *O. fusicaulis* has a cooling point of —1° C. (30.2° F.) and a freezing point of —0.50° C. (31.1° F.), where it remained from 45 to 64 minutes, and then dropped rapidly.

6. *O. ficus indica* from Sicily reached its cooling point at —0.75°C. (30.65° F.) and its freezing point at —0.50° C. (31.1° F.), where it remained from 30 to 38 minutes and dropped afterwards until the temperature of the test tube was reached, which was —20° C. (—4° F.).

SUMMARY OF RESULTS OF TEN EXPERIMENTS WITH EACH OF SIX SPECIES AND VARIETIES OF OPUNTIA

Name of plant	Cooling point		Freezing point		Time of freezing	Temp. of the air	
	° C.	° F.	° C.	° F.	Mins.	° C.	° F.
O. castillae	—1.00	30.20	—0.50	31.10	35–44	—20	—4
O. ficus indica, Malta	—0.75	30.65	—0.25	31.55	12–18	—20	—4
O. Ellisiana	—0.75	30.65	—0.50	31.10	20–28	—20	—4
Opuntia sp. Burbank Special	—1.00	30.20	—0.20	31.64	22–30	—20	—4
O. fusicaulis	—1.00	30.20	—0.50	31.10	45–64	—20	—4
O. ficus indica, Sicily	—0.75	30.65	—0.50	31.10	30–38	—20	—4

RESULTS OF OTHER WORKERS

It is interesting to compare the above study with the results of other experimenters with cacti and also with different plants. The different species show a considerable range of temperature for the freezing point and also for the duration of the freezing point. The limited work that has been done on the species of cacti by other investigators gives practically the same freezing point as found in the writer's experiments. This would indicate that cacti have their own biophysical peculiarities.

Muller-Thurgau* in experiments with *Phajus grandifolius*, a tropical orchid, shows that the temperature of the plant in an environment of —7.5° C. (18.5° F.) drops regularly from 15° C. (59° F.) to —2.5° C. (27.5° F.); after this it drops slowly until —6° C.(21.2° F.) is reached. The temperature then rises to —0.5° C.

*Ueber das Gefrieren und Erfrieren der Pflanzen, Landw. Jahrb. 1880.

(31.1° F.), where it remains for about 4 minutes, after which it drops regularly and gradually to —6.75° C. (19.85° F.) in 41 minutes.

In his experiment with potatoes, Muller-Thurgau found that the temperature dropped regularly from 15° C. (59° F.) to 2° C. (35.6° F.) From the latter to —3.3° C. (26° F.) it dropped more slowly; after that the temperature rose rapidly to 2° C. (35.6° F.) and remained there for 70 minutes. With this the air in the experiment was changed to 15° C. (59° F.) so the freezing experiment could be carried no further.

Muller-Thurgau gives a long list of freezing points of different plants, from which several well-known species have been selected for comparison with the freezing points of cacti.

TABLE OF FREEZING POINTS OF DIFFERENT PLANTS.

	Cooling point		Freezing point		Temp. of air		Remarks
	° C.	° F.	° C.	° F.	° C.	° F.	
Opuntia maxima..	—1.16	29.91	—0.15	31.73	—4.50	23.90	Stem.
Cineraria hybrida	—2.40	27.68	—2.00	28.40	—7.50	18.50	Very young leaf.
Datura arborescens	—4.30	24.26	—1.25	29.75	—5.50	22.10	Old leaf.
Ficus repens.....	—7.10	19.22	—4.05	24.71	—14.5	5.90	Young leaf.
Ficus repens.....	—8.00	17.60	—8.00	17.60	—11.0	12.20	Old leaf.
Fuchsia fulgens...	—2.35	27.77	—1.75	28.85	—8.5	16.70	Young leaf.
Hedera helix	—3.45	25.79	—2.18	28.07	—4.2	24.44	Old leaf.
Bean	—6.30	20.66	—1.10	30.02	—8.0	17.60	Leaf.
Sempervivum tabulaeforme.	—6.48	20.33	—0.55	31.01	—7.50	18.50	Fresh leaf.
Thuyopsis dolobrata.	—6.20	20.84	—0.57	30.97	—16.0	3.20	Twig.
Corn.....	—7.35	18.77	—2.60	27.32	.....	.....	
Fruits of:							
Grape (Riesling)	—7.85	17.87	—3.10	26.42	—12.0	10.40	
Apple (Canada Reinnette)	—2.10	28.22	—1.40	29.48	—14.0	6.80	
Potato, containing sugar.	—4.30	24.26	—1.40	29.48	—9.00	15.8$_0$	

Comparison of results

The results of the writer's work with cacti closely resemble those which Muller-Thurgau obtained with *Opuntia maxima*. He obtained a relatively high cooling point, and a freezing point a little below the temperature at which water freezes, while with other plants he obtained both a lower cooling point and a

relatively lower freezing point. Corn, with a cooling point of —7.35° C. (18.77° F.) and a freezing point of —2.60° C. (27.3° F.), and fruits of grapes, with a cooling point of —7.85° C. (17.87° F.) and a freezing point of —3.10° C. (26.4° F.), may be cited as examples.

The above data follow very distinctly the laws of the freezing of solutions, as stated by Raoult, who says: "If one dissolves in any selected solvent equimolecular quantities of different substances, the freezing point is lowered the same amount in all cases." Also, "the lowering of the freezing point is proportional to the size of the molecule of the dissolved substance."*

The different temperatures at which cell-sap freezes is here very apparent. Corn and grapes contain a high percentage of organic and inorganic matter in the water of the vacuoles. It is the great amount of sugar in the grape which gives to the fruit so low a freezing point.

Opuntia maxima, with which Muller-Thurgau worked, and the spineless cacti, with which the writer worked, on the other hand, have freezing points very little below that of pure water. It follows, therefore, that the dissolved matter in the large amount of water in the cacti is very small. This is not surprising when we consider that the water in these plants is principally storage water, which has been gathered by the plants during the rainy seasons and which enables the plant to carry itself through long droughty periods such as are characteristic of the arid plains of the southwestern parts of the United States and of adjacent Mexico.

On the other hand, the water of corn, grape, and similar plants, is imbibition water which serves to carry the inorganic solutions from the roots to the young cells, and also assists in distributing different organic soluble substances from one part of the plant to another. It also takes part in the synthesis of carbohydrates. In other words, it is water that is used for the time being and must be replaced regularly. This constitutes the important difference.

Another factor worth noting is the length of time required to convert all the water of the plant into ice, as is shown in the table and in Figs. 6, 7, and 8. It is not the same with all species of cacti. *Opuntia fusicaulis* took 45 minutes or more, and in one case 64 minutes, while *O. ficus indica*, which was introduced from the island of Sicily, required only 12 to 18 minutes.

*See also W. Nernst, Theoretical Chemistry, 1899, pp. 116 and 500.

The above facts, however, are entirely independent of both cooling point and actual freezing point, and, as we will see later, are also independent of the degree of cold required to kill the plants.

Without doubt the duration of the freezing point is related directly to respiration, which the plant is able to perform at low temperatures until the water is entirely frozen, at which time the protoplasm probably becomes dormant. This freezing of the water takes place at the end or about the end of the nearly straight line in the diagrams. As already noted, this line is shorter in some species of cacti than in others. The curve is quite constant for the same species, but there appears to be no relation between the length of this line and the cold resistance of a species.

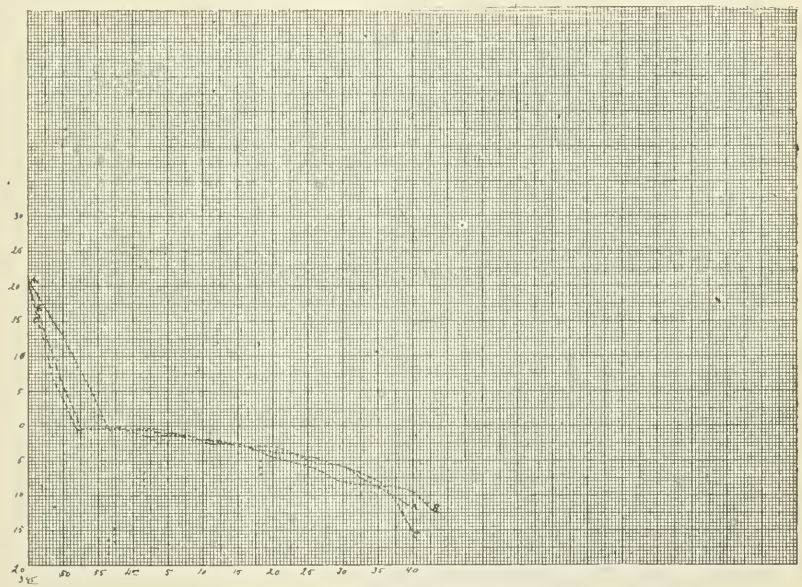

Fig. 9.—Curves showing the freezing of dead tissues of spineless cacti, including *Opuntia* sp. Burbank Special, *O. fusicaulis* and *O. ficus indica*. Compare with curves of living tissues.

It is interesting to observe the character of the curve when pieces of recently killed cactus stems are substituted for the living ones. These show a very much shorter line, which soon becomes strongly curved downward, as shown in Figure 9. This line is practically the same for *Opuntia ficus indica*, *Opuntia* sp. Burbank Special, and *O. fusicaulis* after the freezing point is reached. Similar results were obtained with other species.

The similarity of the curves of freezing in the dead tissues of the cacti is due purely to a physical condition, while the differences in the curves of the living tissues is due to a biophysical condition. The absence of living protoplasm in the cells appears to be responsible for the differences observed in the curves.

EFFECTS OF FREEZING THE TISSUES

Taking up the third problem, it is well known that in freezing plants ice generally appears first in the intercellular spaces of the tissues. Since these intercellular spaces normally contain air and not water, the presence of crystals of ice in them suggests that previous to freezing the water must have been secreted from neighboring cells with the lowering of the temperature. This low temperature causes the water to separate from the cell solutions and freeze. This leaves the remaining cell-sap solution stronger in soluble substances, and consequently a lower temperature is required to cause more of the water to separate and freeze. It is easily understood that the cell contains a stronger sap solution after a part of the water has frozen. In some plants this solution may become strong enough to kill the protoplasm of the cells affected.

The small amount of material which is dissolved in the storage water in cacti is so unimportant that it can do little or no harm to the protoplasm of the cells, even when relatively low temperatures have caused a large amount of the water of the cell-sap solution to be secreted and frozen.

With certain precautions the behavior of the frozen plant tissues may be studied easily under the microscope. A Ganong temperature stage which serves as well for studying the behavior of the protoplasm under low as under high temperatures was used. For this study the stage was fixed in the usual way to the microscope, and the triangular copper basin was filled with a mixture of crushed ice and salt. To lower the temperature further, a vessel was filled with the same freezing mixture, in which the triangular copper basin of the temperature stage was partly embedded. In this way the metallic part of the temperature stage, which is protected by a thick felt covering to prevent radiation, and which is located directly above the stage of the microscope, could be kept easily at a temperature of —5° C. (23° F.). The temperature, however, could not be reduced below this point. The holes in the sides of the temperature stage where the glass slide is inserted were filled with cotton batting to assist in maintaining a uniformly low tem-

perature. With this it was easily possible to study the changes taking place in the protoplasmic cells at the low temperature noted. Ice, in the form of both needle and disk-shaped crystals, was first observed to form on the walls in the intercellular spaces between the cells and above them. When the freezing mixture was removed and also the small pieces of cotton from the openings, the ice that had formed in the intercellular spaces melted gradually, and practically all the water resulting was absorbed again by the cells. With the low temperatures no movement of the protoplasm could be seen, but with the gradual rise of temperature following the removal of the bits of cotton and the freezing mixture, a slow movement of the protoplasm was observed, which became faster with the rise of temperature of the slide. This experiment was repeated several times with the same section of tissue without killing the protoplasm.

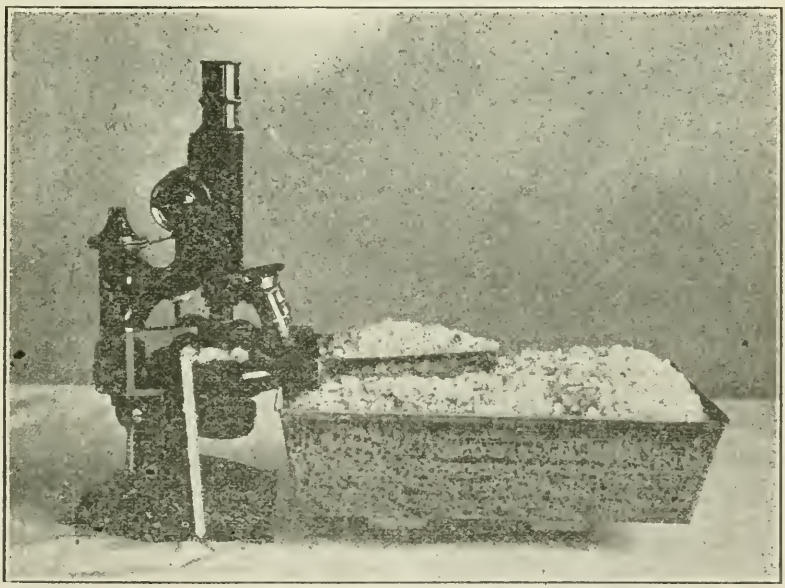

Fig. 10.—Apparatus used for studying the effects of low temperatures and of freezing on the protoplasm of cacti.

The same results were obtained by putting parts of the cactus stems in test tubes at temperatures slightly below the freezing point of water. This was repeated several times, allowing the sections in each instance to come to the temperature of the room, without injuring the protoplasm. These experiments proved that the protoplasm in the cells of the cacti was not injured (1) either as a result of the separation of at least a large part of the water from

the cell sap, and its freezing in the intercellular spaces, or (2) by the condensation of the cell sap as a result of the water being removed. The second and third problems, are, therefore, answered.

EFFECTS OF COLD ON THE PROTOPLASM

The only other cause that might result in the death of the plant or parts of the plant is the inability of the protoplasm to withstand temperatures below a certain point. It is not to be presumed that the protoplasm would be killed as a result of the destruction of the enzymes of the cell, since these are able to withstand low temperatures uninjured.

To determine this, pieces of stems of the various species and varieties of spineless cacti were subjected to a killing temperature of —20° C. (—4° F.). To do this, a large-sized ice-cream freezer containing the ordinary freezing mixture of ice and salt was used. This gave a temperature of —20° C. (—4° F.). The cactus stems were allowed to remain at this temperature for 48 hours, and the ice and salt mixture was replenished from time to time. When removed from the freezer the stems were frozen hard, and upon thawing gradually it was evident that they had been killed, since they had lost their turgor, and the water in the stems was not absorbed by the protoplasm. Other tests also indicated that the protoplasm was dead.

Along with this experiment small pieces of the cactus stems were fitted carefully about bulbs of thermometers which were inserted in large test tubes, the ends of which were closed with cotton batting. These test tubes were placed in a mixture of ice and salt and allowed to remain until the temperature reached —20° C. (—4° F.). This length of time, as before noted, varied with different species. When this temperature had been reached, the thermometers with the pieces of cacti attached were removed, and the protoplasm was studied. The pieces of cacti were frozen hard. After thawing gradually there was every indication that the protoplasm was dead. The cells had lost their turgor, and the protoplasm did not absorb water. Microscopic study showed that the cells were plasmolyzed and the protoplasm had collected toward the centers of the cells in shapeless masses. The nuclei were shrunken, and the chloroplasts had lost, in part, their roundish shape. This protoplasm stained immediately with a solution of eosin in water, which condition will not obtain with living protoplasm. The cells had lost their former outline and the intercellular spaces were greatly enlarged. This latter,

however, would not result in the death of the cells, as plant tissues which have been frozen but not killed often show more or less enlargement of the intercellular spaces. This was true with all species of cacti studied. It is clear, therefore, that the protoplasm was killed by certain low temperatures which it could not withstand. With our present knowledge of chemical and physical phenomena of life, it is not possible to study the internal behavior of the protoplasm at the time when the temperature is fatal.

It is of both scientific and economic importance to determine at just what temperatures these different species are injured and killed by the cold, since some are able to withstand lower temperatures than others. When a cactus plant is injured somewhat—i. e., only parts of the joints are killed, the plant may recover and make good growth the following season. In the numerous experiments performed in this part of the work, the results of which are summarized in the table below, it was found that the same low temperature which would injure a piece of cactus stem would kill it if continued for some time, or if repeated five to eight times. Such a temperature, therefore, must be regarded as the killing temperature. The less hardy varieties, like *Opuntia ficus indica* and *Opuntia* sp. Burbank Special, were injured with temperatures between —5° and —6° C. (23° and 21.2° F.) and were killed when subjected to these temperatures several times. On the other hand, *Opuntia castillae* and *O. Ellisiana* were injured at temperatures of —14° and —16° C. (6.8° and 3.2° F.), respectively. It is interesting to observe that there is no great difference between the temperature which will injure a plant and the temperature which is fatal to the plant in a short time.

TABLE SHOWING TEMPERATURES AT WHICH PIECES OF CACTUS STEMS WERE DAMAGED AND ALSO KILLED OUTRIGHT, WITH DIFFERENCES IN TEMPERATURE

Name of plant	Plant damaged		Plant killed outright		Difference in temp.	Temp. of surrounding air	
	° C.	° F.	° C.	° F.	° C.	° C.	° F.
Opuntia castillae	—14	6.8	—17	1.4	3	—20	—4
Opuntia sp. Burbank Special	— 6	21.2	— 8	17.6	2	—20	—4
O. ficus indica, Malta	— 5	23.0	— 6	21.2	1	—20	—4
O. Ellisiana	—16	3.2	—18	—0.4	2	—20	—4
O. tusicaulis	— 8	17.6	—10	14.0	2	—20	—4
O. ficus indica, Sicily	— 5	23.0	— 8	17.6	3	—20	—4

From the above table it is observed that *Opuntia castillae* and *O. Ellisiana* are resistant to lower temperatures than any of the other species experimented with, being injured at −14° and −16° C. (6.8° and 3.2° F.), respectively, and that *Opuntia ficus indica* from both Malta and Sicily and *Opuntia* sp. Burbank Special are least resistant to cold. These species show injury at temperatures of —5° and—6° C. (23° and 21.2° F.), respectively. Another species, *Opuntia fusicaulis*, was injured at a temperature of —8° C. (17.6° F.). As will be shown later, these results coincide with observations made under field conditions during the winter of 1915–16.

In this work it must be remembered that only pieces of cactus stems were used and that for the most part these were protected by the thick integument of the cactus on but two sides, above and below, while the cut surfaces were naturally without the protection of the integument. Since experiments, the results of which are given on page 10, indicate that a considerable length of time is required for the low temperatures to penetrate the integument, it is to be inferred that uncut joints would resist the same low temperature for a greater length of time. This, however, represents only difference in the length of time required for the penetration of the low temperature. It would not enable the protoplasm to endure a greater degree of cold.

BEHAVIOR OF PLANTS OF SPINELESS CACTI GROWING IN THE INTRODUCTION GARDEN AT THE UNIVERSITY FARM DURING THE WINTER OF 1915–1916

The first frost of any note during the winter of 1915–16 occurred on the night of December 16–17, when the temperature dropped to —1.50 C. (29.3 F.). None of the species of cacti was injured. A little later there were several cold nights when the temperature dropped as low as —4° and —6° C. (24.8° and 21.2° F.). With these temperatures some injury was done to plants of *Opuntia ficus indica* and *Opuntia* sp. Burbank Special. This was particularly true of the younger and partly immature joints, which lost their color and turgor and began to shrink.

On December 28, the temperature dropped to —7.20° C. (19.04° F.) on the University grounds, the corresponding temperature at the University Farm being one or two degrees lower. With this, considerable damage was done to plants of *Opuntia ficus indica* and *Opuntia* sp. Burbank Special growing at the University Farm. The ends, also, of the less mature joints of *Opuntia fusicaulis*

were injured. No damage was done to plants of *Opuntia castillae* or *O. Ellisiana*, which remained in excellent condition throughout the winter. Plants of *Opuntia castillae* growing on the University grounds and also in several parts of Tucson showed no injury from cold.

The lowest temperatures recorded on the University grounds during the months of January and February, 1916, were —5° C. (23° F.) on the night of January 11–12, and —5.6° C. (21.9° F.) on the night of February 1–2. There are no temperature records at the University Farm for these dates, but it is safe to assume that the minimum temperatures there were one or two degrees lower than those given above. During these cold nights plants of *Opuntia ficus indica* and *Opuntia* sp. Burbank Special were slightly injured.

SUMMARY

1. In this study it has been found that the species of spineless cacti having relatively thick integuments are more resistant to low temperatures than those having somewhat thinner integuments, as the penetration of low temperatures through a thick integument is slower than through a thinner one. The term integument is used here to include the cuticle, epidermis, crystal-bearing layer, and several layers of thick-walled cells lying immediately below. The thick integument may be an accidental rather than a developed character. Since our lowest winter temperatures are often of short duration, a cactus plant having a thick integument may pass through such a period practically uninjured, even though the temperature may be low enough to be fatal to the protoplasm. A thick integument protects a cactus plant against sudden and severe temperature changes at any season.

2. The freezing point of the cell-sap of the cactus plant is very little below 0° C. (32° F.), the freezing point of pure water. This suggests that the soluble substances in the cell-sap of cacti are very diffuse. The ordinary cactus contains as much as 90 per cent water.

3. The collecting and freezing in the intercellular spaces of the water from the cells is not in itself particularly harmful to the plant. Neither is the protoplasm poisoned with the concentration of the cell-sap solution as a result of at least a part of the water being withdrawn and frozen.

4. The protoplasm of these plants can withstand without injury a certain low critical temperature, but a temperature below this

is fatal. Injury by frost of a normal cactus plant—i. e., one healthy and of mature growth, is due to the temperature falling below the point which the protoplasm can endure.

5. This study indicates that *Opuntia castillae* and *O. Ellisiana* are resistant to lower temperatures than the other species of spineless cacti studied, being injured at temperatures of —14° and —16° C. (6.8° and 3.2° F.), respectively, while *Opuntia ficus indica* and *Opuntia* sp. Burbank Special were injured with temperatures of —5° and —6° C. (23° and 21.2° F.), respectively. These results agree in general with observations made on these same species under field conditions.

6. The temperature which damages a plant to any extent will kill the plant if continued long enough or if repeated several times. This may be regarded as the "killing" temperature.

7. The reason that one species of cactus endures more cold than another is because of a difference in the character of the protoplasm, due allowance being made for the thickness of the integument when the cold extends over only a short period.

University of Arizona

Agricultural Experiment Station

Bulletin No. 80

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Root tip of corn grown in water culture and poisoned by 1:200,000 of Cu in $CuSO_4$ solution. Copper colored red by means of potassium ferrocyanide. Red shows black in photomicrograph. × 55 diam.

CERTAIN EFFECTS UNDER IRRIGATION OF COPPER COMPOUNDS UPON CROPS

By R. H. Forbes

Tucson, Arizona, December 15, 1916

UNIVERSITY OF ARIZONA
AGRICULTURAL EXPERIMENT STATION

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BY

R. H. FORBES

TUCSON, ARIZONA, DECEMBER 15, 1916

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PREFACE

Two of the great industries of the Rocky Mountain region, both of which have developed within comparatively recent years, are copper mining and irrigation farming. Commercially, these important industries have every reason for harmony with each other. The operations of the copper miner build up busy cities, initiate improvements in transportation and develop populations which must be fed. The irrigation farmer, on the other hand, produces abundant and wholesome supplies of foodstuffs upon which copper-mining communities depend and in return for which they pay good prices. Incidentally, however, to the rapid expansion of these two industries in Arizona and elsewhere in the west, points of contact have developed requiring adjustment. One of these has been in connection with the disposition of mining wastes, including smelter gases and tailings from which the values have been abstracted. In relation to tailings, enormous quantities of which are produced from low-grade ores, considerable study has been devoted in Arizona by scientific agencies and by the copper companies themselves, to the problem of their satisfactory disposal. The object of such disposal is, on the one hand, to keep injurious substances, both insoluble and soluble, away from irrigated crops and, on the other hand, to make some use of them by the mines themselves.

The result of these studies has been, thus far, to devise economical means for impounding almost the whole of the solid wastes from some of the mines, thus avoiding injury to subjacent lands and conserving such values as may yet remain unextracted in the ores. It seems likely, in fact, that by means of improved methods now under consideration, these values may be economically reclaimed.

The question of the toxic effects upon crops of soluble salts of copper which cannot be withdrawn from solutions that escape into irrigating streams, is the one with which this publication is mainly concerned.

The outcome of the attention which has been devoted by farmers and copper companies to the "tailings question" in Arizona is a happy solution of a once formidable controversy; and the establishment of a precedent which will be of great value in time to come in the adjustment of similar differences throughout the Rocky Mountain region.

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PLATE I

Corn root-tips killed in a solution of 1 part copper to 100,000 of water, and colored by means of (1) caustic potash, which gives the violet biuret reaction, identifying both copper and protein; (2) hydrogen sulphide, brown; (3) potassium xanthate, yellow; and (4) potassium ferrocyanide, red. ($\times \pm 30$ diam.)

CERTAIN EFFECTS UNDER IRRIGATION OF COPPER COMPOUNDS UPON CROPS

By R. H. FORBES

Part I.— EXPERIMENTAL WORK

INTRODUCTION

The region to which the studies described in this publication more particularly relate lies in southeastern Arizona in Greenlee and Graham counties and consists, first, of the Clifton-Morenci mining district and second, of the irrigated lands along the Gila River from twenty-five to sixty miles below. The Clifton-Morenci mining district is drained by Chase Creek into the San Francisco River, which in turn empties into the Gila. From the Gila, beginning at a point about twenty-five miles by channel below Clifton, irrigating waters are withdrawn for the use of the rich lands extending somewhat discontinuously from above San Jose to Fort Thomas, a distance of thirty miles. For about forty years, this up-stream mining district and the irrigated lands below have developed together from small beginnings into large industries.

Beginning with the initiation of smelting operations on the San Francisco River in 1882, comparatively small amounts of mining detritus must have found their way into the irrigating water-supply. Following the discovery, in 1893, of immense deposits of low-grade sulphide ores in the district and the erection of concentrating plants to handle them, rapidly increasing quantities of fine slimes were discharged into the stream-flow, becoming noticeable in the irrigating waters of Graham County about the year 1900. Following the observation of their presence, various crop failures were attributed from time to time to the tailings, resulting finally in a request by the farmers of the district to the writer, for an examination of the facts relating to damage done by mining detritus to their irrigated crops.

Following this request, the writer began a study of the problem in May, 1904, which resulted in the publication of Bulletin 53 of the Arizona Agricultural Experiment Station, September 20, 1906. This publication established the fact that irrigating sediments, in general, may be beneficial or harmful according to their composition and physical character and to the manner of their disposition in or upon the soil. If allowed to accumulate upon the surface of the soil in the form of more or less impervious silt-blankets, their influence, by limiting the supply of water and air to the soil, is notably harmful. In the case of the mining wastes from the Clifton-Morenci district, which are particularly plastic and "tight" in character, the damage done was found to be greater than that resulting from sediments arising from ordinary erosion. It was determined that the damage from these wastes, particularly to alfalfa and other crops which cannot receive constant and thorough cultivation, was of an increasingly serious character.

The farmers of Graham County, represented by one of their number, finally brought suit against the Arizona Copper Company, Limited, for discharging tailings into their irrigating water-supply. The case was decided in the District Court of Graham County in favor of the farmers, and an order was issued in November, 1907, effective May 1, 1908, restraining the mining companies from discharging "slimes, slickens or tailings" into Chase Creek, the San Francisco River, or the Gila River. The case was appealed to the territorial Supreme Court where, however, the decision was confirmed in March, 1909. The case was again appealed by the Arizona Copper Company to the Supreme Court of the United States, where it was again and finally decided in favor of the farmers on June 16, 1913.

During and since the occurrences above mentioned, large quantities of solid wastes have been impounded by the copper companies in settling basins constructed for their storage in the district. Recent investigations by the companies indicate a possibility that with copper at 15 cents a pound these stored tailings, which average about 0.85 per cent copper, may be profitably reworked.

In the long run, therefore, it may be found that an adjustment based upon a complete and impartial statement of facts relating to the tailings situation is beneficial both to the agricultural and to the mining interests concerned.

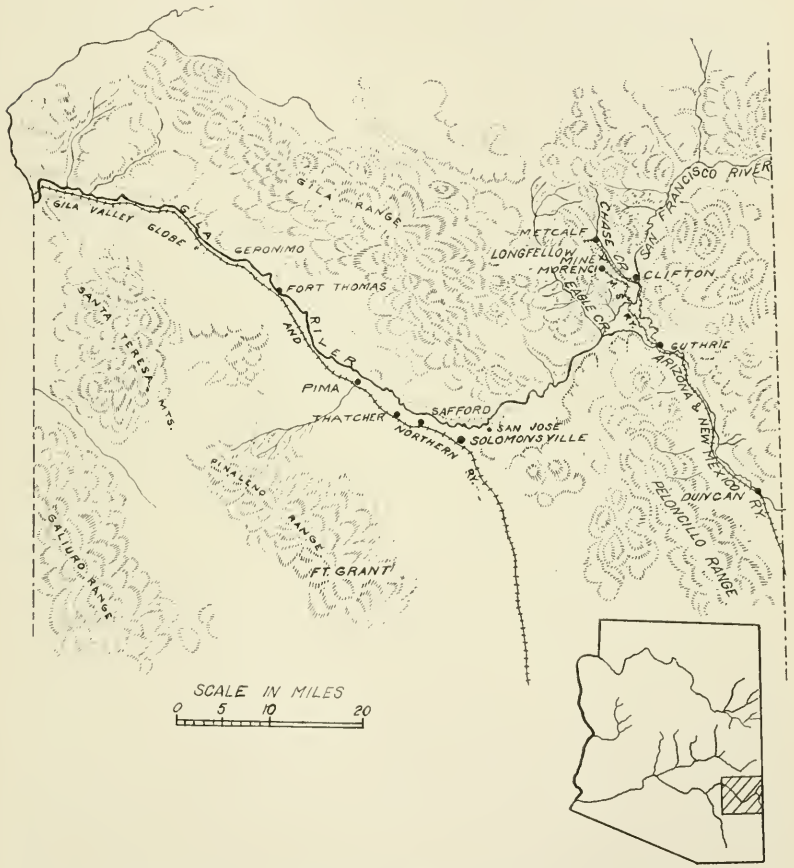

Fig. 1.—General map of the Clifton-Morenci and Gila River mining and irrigation district, Arizona

SOLUBLE COPPER COMPOUNDS

Following the disposition of mining detritus, there remained the problem of soluble copper compounds which, in small but continuously appreciable quantities, find their way with waste waters into the stream-flow of the region. These compounds

originate in the ores of the district and are, as in the case of the carbonates, directly soluble to a slight extent in drainage waters, especially in the presence of carbon dioxide. In other cases, the original ores are changed through the action of air into soluble substances which then escape downstream. Sulphide ores are thus oxidized in the presence of air into soluble copper sulphate. Inasmuch as it is well known that minute amounts of copper in solution are extremely toxic to plant roots directly exposed to them, some apprehension naturally existed as to the effects of these small amounts of copper salts escaping into the water-supply of an irrigated district.

In some respects, conditions were especially favorable here to the successful prosecution of a study of the foregoing question. The irrigated lands are at a distance of twenty miles or more from the smelters, so that injurious gases could not complicate effects upon irrigated crops. There are, also, only traces of other toxic metals to be found within the district—more particularly, arsenic, antimony, and zinc. Injurious effects due to the possible toxic action of compounds originating in the mines are therefore limited to copper.

Scientific study relating to toxic effects of copper upon plants under varying conditions has thoroughly established not only the fact that copper compounds are extremely toxic to plants when they obtain entry to their tissues, but also that various agencies standing between these poisonous salts and the living plant tend to prevent injury.[1] Soluble copper compounds, for instance, react with carbonate of lime, commonly abundant in soils of the arid region, to form the solid carbonates of copper. The partly decomposed silicates of these soils also precipitate soluble compounds of copper and mask their toxic character. Organic matter in the soil likewise holds large quantities of copper in comparatively harmless combinations. Through physical attraction or *adsorption,* soluble copper compounds enter into weak combination with fine soil particles and toxic effects are thereby greatly lessened. In the presence, also, of other soluble salts, such as the various forms of "alkali" commonly found in

[1] See Bibliography, pp. 236–237, references 1, 8, 14, 15, 16, 19, 34, 51.

the soils of the region, the toxicity of copper compounds is enormously lessened.

The investigations recorded in this publication include: (1) Observations upon the distribution of copper in mining wastes, in irrigating waters, in soils and soil waters, in the plants, and in the animal life of the region. (2) The development of accurate methods for the determination of minute amounts of copper in all situations where they may occur. (3) Plant cultural work with waters and in soils in the presence of varying proportions of copper and under varying conditions. (4) A careful analytical study of the results of such cultures in order to determine the symptoms of poisoning and the distribution of copper throughout poisoned plants; and to identify, if possible, the particular parts of plants and tissues injured by copper. (5) A physiological study of plant reactions with copper. (6) Field studies for the purpose of relating the results of laboratory investigations to the question of economic injury done by copper salts to irrigated crops.

By reason of interruptions due to other duties, it has required a long time to mature this investigation to the point where it seems sufficiently complete for publication. This delay, however, has given perspective to the work and, especially, opportunity to verify earlier conclusions as applied to field conditions.

The writer is indebted for painstaking analytical work to Messrs. R. G. Mead, Edward E. Free, Dr. W. H. Ross and C. N. Catlin, associated with the Arizona Agricultural Experiment Station from time to time; and to the helpful advice of Dr. Howard S. Reed, of the University of California Graduate School of Tropical Agriculture, in connection with the physiological part of the work herein described. The publication, also, has been criticized to its advantage by Dr. C. B. Lipman of the University of California.

DISTRIBUTION OF COPPER COMPOUNDS THROUGHOUT THE CLIFTON–MORENCI AND GILA RIVER MINING AND IRRIGATION DISTRICTS

Sources of Copper

The original source of the copper found in this district, according to Lindgren,[2] is a Cretaceous or early Tertiary intrusion of acidic porphyries to which, in the Clifton-Morenci district, all ore deposits may be finally referred. The original porphyries contain as little as 0.02 per cent of copper ore in the form of chalcopyrite. Under the influence of superheated waters emanating from the porphyry, this chalcopyrite, together with other metallic compounds, was carried out from the molten intrusive mass into adjoining strata and there deposited, especially along fissures, in the form of concentrated masses or veins of chalcopyrite and other minerals. Through erosion these deposits were afterward subjected to atmospheric oxidation, followed by downward percolation and a period of secondary enrichment due to numerous reactions mainly between the oxidized compounds of copper and other minerals present.

In limestones and shales, these processes resulted in the formation of oxidized ores containing azurite, malachite, chrysocolla, and cuprite. In porphyry, the main final result was chalcocite or copperglance, the principal constituent of the sulphide ores of the Clifton-Morenci district.

In general, therefore, the metasomatic changes associated, first, with superheated waters arising from the original intrusion of molten porphyry and, second, with meteoric waters percolating downward with oxidizing effects through copper-bearing rocks,

[2] U. S. Geological Survey, Professional Paper No. 43, 1905.

have brought copper from a concentration of possibly less than 0.02 per cent in the original porphyry through every degree of richness to the condition in some cases of pure copper.

Processes by which Copper is Added to the Water-Supply

To a slight extent, drainage waters from the ore deposits and from the mines, containing considerable amounts of copper in solution, find their way downstream. But by far the larger part of the copper which gets into the irrigating supply is derived from the ores and tailings which, in the concentrators, on the dumps, and finally in the river itself, are subjected to the action of atmospheric oxygen, and water containing carbon dioxide and various salts in solution. The residual chalcocite in tailings from sulphide ores thus reacts with oxygen from the air and yields copper sulphate in solution. This, in turn, reacts with the excess of bicarbonate of lime ordinarily contained in the waters of the San Francisco and Gila rivers. The resulting basic carbonate of copper is notably soluble in water containing carbon dioxide and certain of the various salts commonly found in river waters. The residues of carbonates of copper in oxidized ores are directly dissolved in waters containing carbon dioxide and certain soluble salts.

Along with minute quantities of copper thus dissolved and carried forward, pass the solid residues discharged from the concentrators—solid wastes which find their way, unchanged, downstream and finally upon the soils of irrigated fields. At this point begins another and very important series of reactions between dissolved copper compounds and the soil, tending in general to withdraw copper from its solutions and precipitate it in the form of less harmful solid compounds. These are briefly referred to above and will be discussed more in detail further on in this paper. Opposing these precipitations of copper are those solvents which tend to maintain this metal in soluble form in small quantities in the soil. Chief of these is carbon dioxide, which is always present in agricultural soils in significant quantities. Of interest in this connection is the fol-

TABLE I

SOLUBILITIES OF COPPER COMPOUNDS

Compound	Solvent	Cu dissolved, parts per million	Reference
Malachite $CuCO_3.Cu(OH)_2$	Water containing 0.12% carbon dioxide	29.0–31.0	E. E. Free, Journ. Am. Chem. Soc., XXX, 9, p. 1367
Precipitated basic copper carbonate	Pure water	1.5	E. E. Free, Journ. Am. Chem. Soc., XXX, 9, p. 1370
Precipitated basic copper carbonate	Water containing 0.12% carbon dioxide	34.8	E. E. Free, Journ. Am. Chem. Soc., XXX, 9, p. 1370
Precipitated basic copper carbonate	Water containing 0.13% carbon dioxide and 0.01% sodium chloride	36.0	E. E. Free, Journ. Am. Chem. Soc., XXX, 9, p. 1371
Precipitated basic copper carbonate	Water containing 0.13% carbon dioxide and 1.0% sodium chloride	58.0	E. E. Free, Journ. Am. Chem. Soc., XXX, 9, p. 1371
Precipitated basic copper carbonate	Water containing 0.12% carbon dioxide and 0.01% sodium sulphate	37.0	E. E. Free, Journ. Am. Chem. Soc., XXX, 9, p. 1372
Precipitated basic copper carbonate	Water containing 0.12% carbon dioxide and 1.0% sodium sulphate	58.0	E. E. Free, Journ. Am. Chem. Soc., XXX, 9, p. 1372
Precipitated basic copper carbonate	Water containing 0.12% carbon dioxide and 0.01% sod. carbonate	10.0	E. E. Free, Journ. Am. Chem. Soc., XXX, 9, p. 1372
Precipitated basic copper carbonate	Water containing 0.12% carbon dioxide and 1.0% sod. carbonate	0.7	E. E. Free, Journ. Am. Chem. Soc., XXX, 9, p. 1372
Precipitated basic copper carbonate	Water containing 0.12% carbon dioxide and 0.2% calcium sulphate	36.0	E. E. Free, Journ. Am. Chem. Soc., XXX, 9, p. 1372
Precipitated basic copper carbonate	Water containing 0.12% carbon dioxide and 0.11% calc. carbonate	1.4	E. E. Free, Journ. Am. Chem. Soc., XXX, 9, p. 1372
Copper sulphide; CuS	Oxygen-free water	0.09	W. H. Ross, MSS
Chalcopyrite $CuFeS_2$	Pure water	measurable amounts	U. S. Geol. Survey Monograph XLVII, p. 1107
Chalcopyrite $CuFeS_2$	Sodic sulphide	Amt. not stated	U. S. Geol. Survey Monograph XLVII, p. 1106
Malachite	"Insoluble in water, slightly soluble in water charged with carbon dioxide."		Moissan 5, p. 167
Chrysocolla $CuSiO_3.nH_2O$	"Somewhat soluble in water with carbon dioxide"		Lindgren, U. S. G. S. Prof. paper 43, p. 188
Cupric sulphide CuS	Water	1 to 950,000	Comey, Dict. Solubilities, p. 139
Cuprite Cu_2O	"Insoluble in water"		Comey, Dict. Solubilities, p. 137
Cupric oxide CuO	"Insoluble in water"		Comey, Dict. Solubilities, p. 137

lowing table of solubilities of various compounds of copper in different solvents, made up from different sources of information. The exact determinations of solubility by E. E. Free and W. H. Ross were made to obtain data needed in this investigation.

This table indicates that the carbonates and the silicate (chrysocolla) of copper, which are the compounds in which the metal must largely occur in the soil, are notably soluble in aqueous solutions of carbon dioxide.[3] Large amounts of sodium chloride and sodium sulphate increase the solubility of precipitated basic copper carbonate. In pure water, copper compounds, so far as observed, are but slightly soluble. Fluctuations in the content of carbon dioxide and of soluble salts in soil waters, and variations in the character of the soluble salts, are shown to affect the copper content of such waters.

In brief, the final effect upon plant roots of copper in the soil is the complex resultant of many opposing influences tending, on the one hand, to remove copper from solution, and, on the other, to maintain it in toxic soluble form. *Observations on the soil* usually fail to give satisfactory evidence as to the toxic or non-toxic effects to be expected from small percentages of copper that may be present. *Direct chemical and physiological studies of plants* afford much more satisfactory information. This mode of attack has been employed considerably in this investigation.

In view of the general tendency in nature to hinder the movements of copper in soils and to convert it into its insoluble forms, and independently of any tendency of the plant itself to assimilate or to reject copper, we should expect to find relatively small amounts of this element in plant tissues.

The following analytical determinations of copper in ores and tailings were made in samples carefully collected by the writer throughout the district studied. In all cases, the copper was determined electrolytically, manipulations of great delicacy having been developed for the determination of the minute amounts of copper often encountered. A full statement of the methods of preparing samples for analysis, and of determining

[3] Sullivan has shown that powdered silicates react with copper sulphate to withdraw copper from solution; and that this copper will then be redissolved by a solution of potassium sulphate. U. S. Geol. Survey, Bull. 312, 1907.

Fig. 2.—Detail map of the Gila River irrigation district, in Graham County, Arizona.

copper in ores, tailings, waters, soils, and organic materials, is to be found under "Methods of Analysis" in the appendix to this paper. For convenience in comparing widely variable amounts in the samples examined, the copper content is given in parts per million of substance. Parts per million may be reduced to percentages by moving the decimal point four places to the left. For instance, 11,600 parts per million is equal to 1.16 per cent.

TABLE II

COPPER IN ORES AND TAILINGS FROM THE CLIFTON-MORENCI MINING DISTRICT

Sample No. and date	Description of sample	Condition and weight taken, grams	Cu found, grams	Cu parts per million
3491 May 23, '04	One day's run of sulphide ore from from A. C. Co.'s mill in Clifton	1 air-dry	.03195	31,950
3303 May 23, '04	Sulphide tailings, point of discharge from A. C. Co.'s mill, Clifton	1 water-free	.00935	9,350
3438 June 28, '05	Sulphide tailings, point of discharge from A. C. Co.'s mill, Clifton	1 water-free	.0116	11,600
3499 June 28, '05	Sulphide tailings at Clifton coming from Longfellow mill	1 water-free	.00725	7,250
D. C. Co.'s Records May 20, '04	Fine sulphide tailings at Morenci			10,000
3492 May 23, '04	One day's run of oxidized ore from A. C. Co.'s mill at Clifton	1 air-dry	.0553	55,300
3304 May 23, '04	Oxidized tailings, point of discharge from A. C. Co.'s mill, Clifton	1 water-free	.0225	25,500
3439 June 28, '05	Oxidized tailings, point of discharge from A. C. Co.'s mill, Clifton	1 water-free	.0268	26,800
3500 June 27, '05	Oxidized tailings, point of discharge from Shannon C. Co.'s mill, Clifton	1 water-free	.0114	11,400
3309 May 26, '04	Milky sediments, pure tailings from Montezuma Canal, Solomonville	2 water-free	.01725	8,625
3486 June 11, '05	River sediments with tailings from Montezuma Canal, Solomonville	2 water-free	.0067	3,350
3737 Feb. 22, '07	High river sediments with muddy tailings from Montezuma Canal, Solomonville	15.8 water-free	trace	trace
6342 Mar. 4, '16	Floodwater sediments from Montezuma Canal, Solomonville; tailings from Mogollon	.5899	.000085	53

A point of interest to both mine owners and farmers in table II is the large proportion of copper that was discarded with tailings at the time the samples were taken. This loss, so far as these figures show, may amount to almost one-third of the copper

in low-grade sulphide ores (No. 3491, No. 3303), and to nearly one-half in the richer oxidized ores (No. 3492, No. 3304, No. 3439). By far the larger portion of tailings produced, however, are from low-grade sulphide ores, the wastes from which therefore predominate, formerly imparting to river waters the whitish

TABLE III

DISSOLVED COPPER IN RIVER, IRRIGATING, AND GROUND WATERS BELOW THE CLIFTON–MORENCI DISTRICT

Sample No. and date	Description of sample	Condition and amount taken in cc.	Cu found, grams	Cu p.p.m.
3438 June 28,'05	Water mixed with sulphide tailings from A. C. Co.'s mill, Clifton	500	.0009	1.80
3439 June 28,'05	Water mixed with oxidized tailings from A. C. Co.'s mill, Clifton	500	.0018	3.60
3309 May 26,'04	Montezuma Canal water at Solomonville; slight rise in river	2000	.0016	.80
3486 June 11,'05	Montezuma Canal at Solomonville, small flood	6000	.0015	.25
3622 June 25,'06	Montezuma Canal at Solomonville, head waters clear	9000	.00095	.11
3737 Feb. 22,'07	Montezuma Canal at Solomonville, medium flood	14000	.0403	2.88
	Tailings shut out of water supply May 1, 1908.			
4011 Jan. 3,'09	Water from Montezuma Canal at Solomonville	4000	.00031	.08
4029 Apr. 12,'09	Montezuma Canal at Solomonville	3700	.0003	.08
6342 Mar. 4,'16	Montezuma Canal at Solomonville, high water	1000	.00003	.03
3986 Jan. 2,'09	Water from C. & A. Ditch, Bisbee mine waters	3500	.00039	.11
Records of Cananea C. C. Co. Jan. 4,'14	Water from creek below concentrator			2.1
3504 Aug. 19,'05	Water from Geo. Olney's well, 30 ft. deep, east of Safford, under Montezuma Canal	7000	.0037	.53
4012 Jan. 3,'09	Water from Wilson's well, one-half mile west of Solomonville under San Jose Canal	3500	less than .00001	less than .003
3526	Water from University well, Tucson, 95 ft. deep, tapping Rillito underflow	7000	none	none

appearance characteristic of this material. It is of interest to note in this connection that in one instance observed the tailings almost completely maintained their richness in copper between

Clifton and Solomonville. At Clifton, May 23, 1904, the principal discharge of sulphide tailings (3303) was observed carrying 0.93 per cent of copper. At Solomonville, three days later, the Montezuma ditch-water sediments (No. 3309), mostly of this same material, carried 0.86 per cent of copper, indicating the persistence with which the copper accompanies the wastes, with which it is associated, downstream and upon underlying irrigated lands.

TABLE IV

Copper in Soils Irrigated with Tailings Waters

Sample No. and date	Description of sample	Condition and weight taken, grams	Cu found, grams	Cu p.p.m.
3435 May 25,'04	Top 5 in. sedimentary soil (Fred Thorstison), upper end alfalfa field west of Safford, under Montezuma Canal	96.7 water-free	.020	207
3434 June 10,'05	Top 5 in. sedimentary soil (Geo. Olney), upper end alfalfa field east of Safford, under Montezuma Canal	96.8 water-free	.0199	205
3501 Aug. 19, '05	Soil in place at 4 ft. depth beneath No. 3434	96.2 water-free	.0021	22
3436 June 25,'05	Top sedimentary soil (Wm. Gillespie), upper end of test alfalfa field west of Solomonville, under Montezuma Canal	96.7 water-free	.0192	199
3437 June 25,'05	Soil in place, no sediments at surface of lower end of field near No. 3436	94 water-free	.0028	30
3502 Aug. 19,'05	Soil in place at 4 ft. depth beneath No. 3437	96.1 water-free	.001	10
2381 June 5,'00	Surface 12 in. from garden near Pima, Ariz., beyond tailings deposits	100 air-dry	faint trace	trace
3522 Oct. 25,'05	Top 4 in. sedimentary soil upper end of alfalfa field, Station farm near Phoenix, under Grand and Maricopa canals	95 water-free	.0003	3
3521 Oct. 25,'05	Deep soil, no sediments, Station farm near No. 3522	95 water-free	.0003	3
2763 Nov. 11,'01	Surface 12 in. from orange orchard north of Phoenix, under Arizona Canal	100 air-dry	faint trace	trace
1890 Apr. 20,'01	Surface 15 in. from cultivated field west of Tempe, under Tempe Canal	100 air-dry	faint trace	trace
2830 Jan. 19,'00	Surface 12 in. from orange orchard northeast of Phoenix, under Arizona Canal	100 air-dry	none	none

Table III is of interest because it reveals quantities of dissolved copper in irrigating and in ground waters sufficient, under proper conditions, in water cultures, to produce toxic effects upon plants.[4] It is noteworthy, however, that, following the order of the court, effective May 1, 1908, prohibiting the introduction of tailings into the water-supply, the amount of dissolved copper in Montezuma canal waters greatly decreased, due to the decrease in quantity of sulphides whose oxidation affords the supply of dissolved copper. Other water-supplies also are found to contain similar amounts of copper, as the Calumet and Arizona mine waters, used for irrigation below Bisbee. As stated above, however, in the soil itself the toxic action of such copper solutions is enormously decreased. Naturally, the question arises as to the possibility of toxic effects in using such waters upon cultivated soils. This is discussed on subsequent pages. The proportions of copper (0.003 to 0.53 parts in 1,000,000 of water) found in the drainage beneath this irrigated district indicate that not all of the copper applied in irrigation remains in the soil. University well water at Tucson was observed to be free from this element.

Soils Nos. 3435, 3434, and 3436 show maximum amounts of copper, inasmuch as they are composed to a considerable extent of tailings. The soils in place beneath these sediments, Nos. 3501 and 3502, contain much less, yet noticeable amounts of copper, most of which is retained where it first comes in contact with the top soil. It is of interest to note that the surface sediments and the deep soils of the Experiment Station farm near Phoenix, Arizona, irrigated from an entirely different watershed, also contain small but weighable amounts of copper. This was probably derived from mines at Globe and Jerome, Arizona, whose wastes have found their way into the drainage which supplies irrigation for Salt River Valley. The quantities observed, however, three parts copper per million of soil, are negligible. Other soils from Salt River Valley also show traces of copper.

[4] See Bibliography, p. 236, references 5, 18.

TABLE V

Miscellaneous Soils Unaffected by Mining Detritus

Sample No. and date	Description of sample	Condition and weight taken, grams	Cu found, grams	Cu p.p.m.
2375 June 5,'00	Surface 12 in. from new ground near Safford, recently placed under Montezuma Ditch	100 air-dry	none	none
2253 Jan. 3,'00	Surface 12 in. university ground, Tucson	100 air-dry	none	none
3503 May 9,'05	Surface 12 in. virgin unirrigated soil, Colorado Valley bottom near Yuma	100 air-dry	none	none

These determinations, made in widely separated localities, indicate the absence of copper in soils which are not immediately under the influence of mining detritus.

TABLE VI

Copper in Vegetation from Upper Gila Valley Farms

Sample No. and date	Description of sample	Condition and weight taken, grams	Cu found, grams	Cu p.p.m.
3505 Aug. 19,'05	Alfalfa, before blooming, from upper end of Geo. Olney's field east of Safford, under Montezuma Ditch	1206 air-dry	.0062	5.10
3512 Aug. 19,'05	Alfalfa from bale grown in Layton (M. B. Steele) under Montezuma ditch	1359 air-dry	.0077	5.70
3507 Aug. 20,'05	Corn in bloom, leaves only, grown in Layton (Jas. Welker), under Montezuma Ditch	545 air-dry	.0033	6.10
3509 Aug. 19,'05	Wheat from stack, stalk and grain, grown in Layton (M. B. Steele), under Montezuma Ditch	1125 air-dry	.0027	2.40
3513 Sept. 19,'05	Mistletoe, growing on willow 25 ft. above ground, one mile east of Safford, under Montezuma Ditch	1245 air-dry	.0094	7.60
3739	Alfalfa seed, crop of 1906, grown near Pima under Smithville Ditch	782 water-free	.0026	3.33
3741	Alfalfa seed (Wm. Gillespie), crop of 1906, grown near Solomonville, under Montezuma Ditch	843 water-free	.0023	2.72
3780	Shelled corn, crop of 1906, grown at Solomonville, under Montezuma Ditch	932 water-free	.0004	.43
3740	Shelled corn, crop of 1906, grown at Solomonville, under Montezuma Ditch	874 water-free	.0008	.73
3738	Shelled corn, crop of 1906, grown near Pima, under Smithville Ditch	1092 water-free	trace	trace

The prevalence of small amounts of copper in vegetation throughout this locality is shown by the figures in table VI. Samples of corn and alfalfa contained comparable quantities of copper, which, however, were exceeded by the amount found in a sample of mistletoe growing on a willow fully twenty-five feet above the ground. This is due chiefly to the perennial character of mistletoe which, therefore, has more time to accumulate copper. It is interesting to note also that seeds of alfalfa and corn contain less copper than corresponding foliage. Corn leaves were observed to contain 6.1 parts of copper per million parts of air-dry substance, while grain from the same locality contained from 0.73 to 0.43 parts. Alfalfa seed contained about one-half as much copper as the stalks and leaves, while wheat hay carrying a large proportion of grain showed a low proportion of copper. These facts are probably connected with transpiration,

TABLE VII

COPPER IN VEGETATION FROM OTHER LOCALITIES

Sample No. and date	Description of sample	Condition and weight taken, grams	Cu found, grams	Cu p.p.m.
3508 Aug. 25,'05	Alfalfa hay, station farm near Phoenix (two samples)	2109 air-dry 1408 air-dry	.0021 .0031	1.00 2.20
3516 Oct. 25,'05	Alfalfa, before blooming, station farm near Phoenix	1106 air-dry	.0011	1.00
3515 Oct. 4,'05	Alfalfa hay, Colorado bottom, Yuma date orchard	1262 air-dry	none	none
3517 May, 1905	Barley hay, station farm near Phoenix	1304 air-dry	.0002	.15
3518 Oct. 25,'05	Corn, leaves only, station farm near Phoenix	595 air-dry	.0005	.84
3519 Oct. 14,'05	Corn, leaves only, grown on Rillito near old Fort Lowell	284 air-dry	.0018	6.30
3529 Dec. 27,'05	Corn, leaves and bloom, same field as No. 3519	1132 air-dry	.0015	1.32
3520 Oct. 14,'05	Mistletoe from cottonwood 30 ft. above ground, old Fort Lowell, near Tucson	1160 air-dry	.001	.85
3989 Dec. 31,'08	Young (5 mos. old) alfalfa roots from C. & A. ranch irrigated with mine waters containing copper, from Bisbee	2.12 air-dry	.0001	47.00
3990	Corn roots from C. & A. ranch irrigated with mine waters containing copper, from Bisbee	16.7 air-dry	.00025	15.00

which is maximum in leaves and quantitatively small in the fruiting parts of a plant. Additional evidence of this fact is shown in poisoned corn plants, which are discussed on a subsequent page.

Comparing the data of table VII with those of table VI, it is evident that, excluding corn and alfalfa irrigated with C. & A. mine waters, in every case except that of one sample of corn from old Fort Lowell (No. 3519) the copper in crops grown on Gila Valley farms is much in excess of that in plants coming from elsewhere for the same classes of material. The presence of appreciable amounts of copper in samples of alfalfa, corn, barley, and mistletoe also accords with the fact that the soils in which they were grown receive the drainage from copper-bearing watersheds. The one exception, at Yuma (No. 3515) where no trace of copper could be found either in alfalfa or in soil (No. 3503), indicates that these alluvial river deposits, which have been subjected annually to the leaching action of enormous quantities of flood waters, have been prevented from accumulating appreciable quantities of copper.

Copper in the Flesh and Bones of a Pig

In order to follow the copper as far as possible in its transmigrations, a five-months-old pig that had been born and brought up in an alfalfa pasture near Solomonville under the Montezuma Ditch, was killed and portions of the flesh and bones were taken for examination, with the following results:

Sample No. and date	Description of sample	Condition and weight taken, grams	Cu found, grams	Cu p.p.m.
3779		917		
May 7,'07	Liver, heart, and rib meat	fresh	.0053	5.78
3778		998		
May 7,'07	Ribs and rib meat	fresh	.00006	.06

The largest amount of copper was found in portions of liver, heart and rib meat, only minute amounts being present in the bony material. In this connection, it is stated that about two parts of copper have been observed in one million parts of human liver; ten parts in human kidneys, and as much as fifty parts

in sheep's liver.[5] Human food, however, is commonly contaminated with copper compounds, which account for its presence in the human body.

In brief, the observations detailed above have shown the successive positions of copper in the original ores of the Clifton-Morenci district; in the tailings wastes from these ores, in suspension and in solution in river waters exposed to milling operations; in soils irrigated with these waters; in the ground waters beneath these soils; in vegetation growing upon them; and even in the animal life of the region. It is of interest to observe, first, the concentration through natural processes of small amounts of copper in the original rocks into the form of rich ores; and, second, the reversal, through human agencies, of this process, and the dilution of copper values till, in vegetation and in animal life, but traces of the metal can be detected.

DISTRIBUTION OF COPPER IN PLANTS WITH ROOT SYSTEMS EXPOSED TO COPPER COMPOUNDS

CORN PLANTS GROWN IN SOILS CONTAINING COPPER

In order to determine accurately the distribution of copper throughout a typical crop plant, thereby locating if possible the points at which injury may occur from copper compounds in the soil, three lots of corn plants were examined in detail. Two of these were grown (August 3 to November 13, 1907) in pots containing thirty-eight pounds of sandy loam soil very thoroughly mixed with 0.01 and 0.025 per cent of copper in the form of freshly precipitated copper carbonate ($Cu(OH)_2.CuCO_3$), made by mixing equivalent amounts of copper sulphate and sodium carbonate. The third was grown in soil containing 0.05 per cent of copper in the form of finely pulverized chalcocite.

The samples were harvested with care to prevent contamination with copper dust; the root portions being washed in copper-free water saturated with carbon dioxide until the washings contained no trace of copper. Determinations of copper, as

[5] Blyth, Poisons, fourth edition, pp. 640–641.

usual, were made as shown under "Methods of Analysis" (see Appendix herewith). Following are the tabulated results:

TABLE VIII

Eleven Stalks of Corn Grown in Soil Containing 0.01 per cent Copper as $Cu(OH)_2.CuCO_3$ (1907)

No.	Plant part	Weight of sample, grams	Cu found, grams	Cu p.p.m.
3869*p*	Lower six nodes, 24 in. long	43.4	.00012	3.00
3869*q*	Basal sheaths of leaves from lower six nodes	23.2	.0001	4.00
3869*r*	Blades of leaves from lower six nodes	33.1	.00029	9.00
3869*s*	Upper four-seven nodes, 24 in. long	24.2	.00017	7.00
3869*t*	Basal sheaths of leaves from upper nodes	20.6	.00013	6.00
3869*u*	Blades of leaves from upper nodes	19.6	.00024	12.00
3869*v*	Rudimentary ears	11.8	.0001	9.00
3869	Whole top portions	175.9	.00115	6.50
3868	Roots	10.6	.00161	152.00

TABLE IX

Ten Stalks of Corn Grown in Soil Containing 0.025 Per Cent Copper as $Cu(OH)_2.CuCO_3$ (1907)

No.	Plant part	Weight of sample, grams	Cu found, grams	Cu p.p.m.
3865*a*	Five lower nodes, 14.4 in. long	17	.00024	14.00
3865*b*	Basal 12 in. of leaves and sheaths from five lower nodes	17.2	.00037	22.00
3865*c*	Terminal 14 in. of leaves from five lower nodes	14.4	.00047	33.00
3865*d*	Upper five-seven nodes, 14 in. long, including tassels and ears	9.2	.00017	19.00
3865*e*	Leaves from same	19.2	.00035	18.00
3865	Whole top portions	77	.0016	21
3866	Roots	9.2	.0067	728

TABLE X

FOUR STALKS OF CORN GROWN IN SOIL CONTAINING 0.05 PER CENT COPPER AS Cu_2S. (1908)

No.	Plant part	Weight of sample, grams	Cu found, grams	Cu p.p.m.
3968*p*	Lower six nodes	11.5	.00010	9.00
3968*q*	Basal sheaths from lower six nodes	7.5	.00008	11.00
3968*r*	Blades from do.	15.7	.00021	13.00
3968*s*	Upper five-six nodes	3.5	.00004	11.00
3968*t*	Basal sheaths from upper five-six nodes	5.2	.00007	13.00
3968*u*	Blades from do.	4.9	.00010	20.00
3968*v*	Rudimentary ears	3.4	.00005	15.00
	Whole top portions	51.7	.00065	12.50
3978*a*	Fine roots	3.23	.00081	251.00
3978*b*	Coarse roots	2.91	.00024	83.00
	whole root system	6.14	.00105	171.00

In all of the corn samples shown above, the copper content of root systems is very much greater than that in the top portions of the plants, amounting to twenty-three times, thirty-four times, and thirteen times as much, respectively. In the aerial parts of all samples copper increases slightly but uniformly towards the upper and outer portions of the plants. This must be an effect of transpiration, by which copper in solution is carried to the terminal portions of the plant and there deposited. The fine roots of one sample were found to contain about three times as much copper as the coarse roots—a fact which can be explained by the greater proportion of absorbing surface to weight in small roots.

With reference to toxic effects, the culture in 0.01 per cent copper carbonate showed only a faint yellow striping of leaves, with no checking of growth. The 0.025 per cent culture gave leaves which were strongly striped with yellow, and the total growth reduced to less than one-half. Toxic effects evident in the top portions of this culture are manifestly to be associated mainly with the greatly increased copper content of its roots, since total amounts of copper in the top portions remain small. The 0.05 per cent culture of copper in the form of Cu_2S, or finely powdered chalcocite, showed only faint toxic effects in the tops. The following summary indicates the relation between toxic effects and copper content of materials.

Culture	Condition	Cu in tops p.p.m.	Cu in roots p.p.m.	Ratio
Copper carbonate, 0.01% Cu (precipitated)	Leaves faintly striped normal weight	6.50	152.00	1:23
Copper carbonate, 0.025% Cu (precipitated)	Leaves strongly striped three-fourths yellow, half weight	21.00	728.00	1:34
Copper sulphide, 0.05% Cu	Faintly striped leaves, normal weight	12.50	171.00	1:13

In this table a general relation is shown between the toxic effects in the aerial portions of the plant, and the amounts of copper in root systems; but as to the soils employed toxic effects are influenced both by amounts and character of copper compounds present, as is shown further on following pages.

In view of the fact that the small increase of copper in the carbonate cultures, from 0.01 to 0.025 per cent, caused severe toxic effects attended by an increase of copper in root systems from 152 to 728 p.p.m. of dry matter, it seemed desirable to investigate thoroughly the quantitative relations between the copper in roots and the toxic effects as shown in vegetative growth. It was expected in this way to find a means of determining whether a plant contained an injurious or killing dose of copper, just as, analogously, killing doses of poisons in animals may be ascertained. With this end in view cultures of corn, beans, and squashes were grown in water, in pots of soil and in garden plots; and roots and top portions were examined quantitatively for copper.

In preparing samples of roots for analysis, washing with 4 per cent hydrochloric acid was carried out with water cultures, but most of the samples were prepared by washing with large quantities of copper-free water saturated with carbon dioxide, until the washings showed no trace of copper. By still a third method the soil adhering to a sample was analyzed for copper, the ash was then determined and assumed to be soil, and a corresponding amount of copper subtracted from the total found. For details see "Methods of Analysis." All of these methods undoubtedly give conservative figures for copper in root systems inasmuch as solvents not only remove externally adhering compounds but may also gradually act upon the copper content of

root systems. The acid-wash and soil-correction methods give severely minimum results. The carbon dioxide wash used in the majority of analyses is laborious but more satisfactory.

WATER CULTURES (1907)

Cultures of corn, beans, and squash were grown in University of Arizona well-water containing 250 p.p.m. of soluble solids. From 0.03 to 3.0 parts of copper as precipitated carbonate dissolved in carbon dioxide were used in making cultures and the resulting growths of tops and roots were divided into the worst-poisoned and least-poisoned portions, for determinations of copper.

Fig. 3.—Corn cultures, series 121–62, grown in University of Arizona well water, containing from .03 to 3. parts per million of copper as basic carbonate ($Cu(OH)_2.CuCO_3$).

Series Corn 121–62.—Grown in well water containing Cu as $Cu(OH)_2.CuCO_3$ as follows: check, 3.0, 1.0, 0.8, 0.5, 0.3, 0.1, 0.08, 0.05, and 0.03 p.p.m. Cu. December 1–February 27, 1907. Series divided into two portions:

a. Plants not badly poisoned; roots growing; tops showing Cu effects; 0.1, 0.08, 0.05, 0.03 cultures. (Nos. 3694, 3693.)

b. Plants badly poisoned; root growth arrested; tops living; 3.0, 1.0, 0.8, 0.5, and 0.3 cultures. (Nos. 3692, 3691.)

Series Beans 121–66.—Grown in well water containing Cu as $Cu(OH)_2.CuCO_3$ as follows: check, 3.0, 1.0, 0.8, 0.5, 0.3, 0.1, 0.08, 0.05, 0.03 p.p.m. Cu. December 9–February 27, 1907. Series divided into two portions:

a. Least poisoned plants; roots nearly normal, tops normal; 0.3, 0.1, 0.08, 0.05, 0.03 cultures. (Nos. 3702, 3697.)

b. Worst poisoned plants; roots badly affected, tops less affected; 3.0, 1.0, 0.8, and 0.5 cultures. (Nos. 3700, 3699.)

Series Squash 121–66.—Grown in well water containing Cu as $Cu(OH)_2.CuCO_3$ as follows: check, 3.0, 1.0, 0.8, 0.5, 0.3, 0.1, 0.08, 0.05, and 0.03 p.p.m. Cu. December 10–February 27, 1907. Series divided into two portions:

a. Least poisoned plants; roots growing; tops strong; 0.3, 0.1, 0.08, 0.05, and 0.03 cultures. (Nos. 3698, 3701.)

b. Worst poisoned plants; roots dead or nearly so; tops badly affected; 3.0, 1.0, 0.8, and 0.5 cultures. (Nos. 3696, 3695.)

TABLE XI

COPPER CONTENT OF PLANTS IN WATER CULTURES

No.	Series	Condition of sample	Dry matter in grams	Cu found, grams	Cu p.p.m. dry matter: tops	Cu p.p.m. dry matter: roots
3694	Corn, .1, .08, .05, .03	Tops affected	6.3	.00009	14.30	
3693	Corn, .1, .08, .05, .03	Roots growing	2.3	.000236		102.60
3692	Corn, 3., 1., .8, .5, .3	Tops living	4.8	.000056	11.70	
3691	Corn, 3., 1., .8, .5, .3	Roots arrested	2.8	.000572		204.30
3702	Beans, .3, .1, .08, .05, .03	Tops normal	9.4	.000198	21.10	
3701	Beans, .3, .1, .08, .05, .03	Roots growing	2.6	.000157		60.40
3700	Beans, 3., 1., .8, .5	Tops affected	6.6	.000204	30.90	
3699	Beans, 3., 1., .8, .5	Roots badly affected	1.6	.000494		308.80
3698	Squash, .3, .1, .08, .05, .03	Tops strong	10.4	.000333	32.00	
3697	Squash, .3, .1, .08, .05, .03	Roots nearly normal	.6	.000087		145.00
3696	Squash, 3., 1., .8, .5	Tops badly affected	3.6	.000092	26.00	
3695	Squash, 3., 1., .8, .5	Roots dead	.2	.000058		290.00

It is noteworthy, in this series, that the amounts of copper found in roots that still retain the power of growth average about 103 parts in one million of dry matter, as compared with 268 parts in dead roots whose protoplasm is presumably killed as an effect of copper. Badly poisoned roots in every instance show a great excess of copper over those less affected. The tops, on the other hand, do not show copper in proportion to the amounts in the roots, averaging the same amount of copper in badly poisoned (22.9 p.p.m.) and in slightly poisoned (22.5 p.p.m.) plants. Corn was observed to be distinctly more sensitive to copper in water culture than either squash or beans, as was

shown by the method of measuring growth of root tips marked with India ink, and noting points at which growth was retarded (*R*) and arrested (*A*).

TABLE XII

SHOWING POINTS AT WHICH ROOTS WERE RETARDED OR ARRESTED IN GROWTH

Cultures in Cu, in well water, parts per million	.03	.05	.08	.1	.3	.5	.8	1.	3.
Corn		R					A		
Beans				R			A		
Squash				R			A		

Photographs of the three series also indicate an earlier retardation of corn root development than of bean or squash root development; and show additionally that the top portions of cultures are not damaged in proportion to the root systems.

TOXICITY OF COPPER SOLUTIONS TO PLANT ROOTS IN WATER CULTURE

In order to gain some indication of effects in water culture of copper salts upon plants, several series of plants were grown under varying conditions, and effects observed of the kind of copper salts employed, strength of solution used, the kind of plant, and the effects of other salts present.

Solutions were made in water free from copper, twice distilled; or, where permissible, University of Arizona well water, copper-free. The series were arranged, usually, to carry 0.01, 0.03, 0.05, 0.08, 0.1, 0.3, 0.5, 0.8, 1.0, 3.0, and 5.0 parts copper per million of water. The cultures were made in 600-c.c. bottles, covered with pasteboard squares saturated with hot paraffin and perforated with three holes for plant seedlings held in place by cotton.

Effects upon cultures were judged by elongation of roots determined by the usual method of marking with India ink 5 mm. back of root tips and noting growth after twenty-four hours. Corn, beans, and squash were the plants employed and the points

particularly noted were those at which growth was retarded and at which it was arrested.

Table XIII gives the data condensed from the experimental records:

TABLE XIII (*a*)

TOXIC EFFECTS OF COPPER UPON ROOTS OF WATER CULTURES

First experiment (1905)

Culture	Copper salt employed	Kind of water	Cu in solution: Growth retarded between, p.p.m.	Cu in solution: Growth arrested between, p.p.m.
Beans	$CuSO_4$	Distilled		.25—1.25
Beans	$Cu(OH)_2.CuCO_3$	Well		.57—5.7
Cantaloupes	$CuSO_4$	Distilled		less than .25
Cantaloupes	$Cu(OH)_2.CuCO_3$	Well		.57—5.7

Indicating lessened toxicity in well water.

Fig. 4.—Bean cultures (eighth exp.), showing effects of varying concentrations of copper in distilled water and in solutions of mixed salts. *S*, salt solutions; *D*, distilled water; *W*, no copper, and .05 to 3. parts per million of copper.

TABLE XIII (*b*)

Eighth experiment (1905)

Corn	$Cu(OH)_2.CuCO_3$	Salt solution*	.3 — .5	.8 —1.
Corn	$Cu(OH)_2.CuCO_3$	Distilled	less than .01	.1 — .3
Beans	$Cu(OH)_2.CuCO_3$	Salt solution*	.1 — .5	.8 —1.
Beans	$Cu(OH)_2.CuCO_3$	Distilled	.1 — .3	.5 — .8
Squash	$Cu(OH)_2.CuCO_3$	Salt solution*	.1 — .5	.8 —1.
Squash	$Cu(OH)_2.CuCO_3$	Distilled	.1 — .3	.3 — 5

Showing lessened toxicity in salt solution.

* $NaCl$ 64 pts.
Na_2SO_4 2
$CaSO_4$ 7.3
Univ. well water salts 26.1

Total 100 pts. per 100,000.

TABLE XIII (*c*)

Fifth experiment (1905)

Corn	$CuSO_4$	Distilled	.01— .05	.1 — .5
Corn	$Cu(OH)_2.CuCO_3$	Distilled	.01— .05	.1 — .5

Indicating equal toxicity of Cu as sulphate and as carbonate, and (compare second, fourth and eighth experiments) great toxicity to corn in distilled water.

TABLE XIII (*d*)

Third experiment (1905).

Beans	$CuSO_4$	Distilled	.1 — .3
Beans	$Cu(OH)_2.CuCO_3$	Distilled	.1 — .3

Toxicity to beans of Cu as sulphate and as carbonate was the same.

TABLE XIII (*e*)

Seventh experiment (1905)

Squash	$CuSO_4$	Distilled	.01— .05	.1 — .5
Squash	$Cu(OH)_2.CuCO_3$	Distilled	.01— .05	.1 — .5

Toxicity to squash of Cu as sulphate and as carbonate was the same.

TABLE XIII (*f*)

Second experiment (1905)

			Cu in solution	
Culture	Copper salt employed	Kind of water	Growth retarded between, p.p.m.	Growth arrested between, p.p.m.
Corn	$Cu(OH)_2.CuCO_3$	Well	.1 — .3	.8 —1.
Beans	$Cu(OH)_2.CuCO_3$	Well	.1 — .3	.8 —1.

Toxicity of copper as $Cu(OH)_2.CuCO_3$ to corn and beans was the same.

TABLE XIII (*g*)

Fourth experiment (1905)

Corn	$Cu(OH)_2.CuCO_3$	Well	.05— .08	.8 —1.
Squash	$Cu(OH)_2.CuCO_3$	Well	.1 — .3	.8 —1.

Corn was somewhat more sensitive to copper as $Cu(OH)_2.CuCO_3$ than squash.

TABLE XIII (*h*)

Sixth experiment (1905)

Beans	$Cu(OH)_2.CuCO_3$	Well	.1 — .3	1. —3.
Squash	$Cu(OH)_2.CuCO_3$	Well	.1 — .3	.8 —1.

Beans and squash were about equally sensitive to copper as $Cu(OH)_2.CuCO_3$

These experiments, which are not stated in complete detail here, indicate quite clearly:

1. That the toxic effects of copper are less in the presence of the salts ordinarily contained in well waters than in distilled-

water solution. This fact indicates that the toxicity of copper salts in the presence of soil-water solutions is probably minimized.

In all cases it was observed that root growth was much more vigorous in salty than in distilled water, where no copper was used. Lessened toxicity of copper in salty solutions may therefore *in part* be due to greater vigor and resistant qualities of plant cells grown in such solutions.

2. Copper appears to be equally toxic as sulphate or as basic carbonate.

3. Corn is probably more sensitive to copper salts than is squash or beans.

Stimulation Effects in Water Cultures

In view of the debated question as to stimulation of plant growth by minute amounts of copper salts, it is of interest to observe that, quite consistently, the most vigorous root growth is associated with concentrations of from 0.01 to 0.1 parts per million of copper, as shown by details from cultures described on previous pages.

TABLE XIV (*a*)

Stimulation Effects of Copper upon Roots of Plants in Water Cultures

Corn roots grown in well water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Condition
check	23.4 mm.	Tops of plants showing
.01	27.3	increased growth at .08
.03	17.6	and .1 p.p.m.
.05	17.3	
.08	19.4	
.1	18.5	

Showing stimulation at .01 p.p.m.

TABLE XIV (*b*)

Bean roots grown in well water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Condition
check	2.5 mm.	Tops of plants in .08
.01	2.2	and .1 cultures higher
.03	4.7	than in .05, .03, .01, and
.05	2.8	check.
.08	2.5	
.1	2.9	

Showing stimulation at .03 p.p.m.

TABLE XIV (*c*)

Corn roots grown in well water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Condition
check	14.2 mm.	vigorous
.03	17.3	most vigorous
.05	14.4	most vigorous
.08	9.6	retarded
.1	10.3	retarded

Showing stimulation at .03 p.p.m.

TABLE XIV (*d*)

Squash roots grown in well water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Cu p.p.m	Elongation 48 hrs.
check	12.0 mm.	.08	12.3
.03	10.7	.1	13.2
.05	10.0		

Showing no stimulation at these concentrations.

TABLE XIV (*e*)

Bean roots grown in well water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Condition
check	2.4 mm.	Tops strong throughout, showing stimulation at .03, .05, and .1
.03	3.1	
.05	4.5	
.08	2.8	
.1	3.	

Showing stimulation at .05 p.p.m.

TABLE XIV (*f*)

Squash roots grown in well water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Cu p.p.m.	Elongation 48 hrs.
check	13.1 mm.	.08	7.6 mm.
.03	7.4	.1	9.7
.05	8.8	.3	3.7

Not showing stimulation consistently.

TABLE XIV (*g*)

Corn roots grown in well water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Cu p.p.m.	Elongation 48 hrs.
check	9.8 mm.	.1	13.5 mm.
.01	13.8	.3	10.
.05	17.5	.5	3.8

Showing strong stimulation .01 to .1 mm.

TABLE XIV (*h*)

Corn roots grown in distilled water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Cu p.p.m.	Elongation 48 hrs.
check	27.6 mm.	.05	5.7 mm.
.01	1.8	.1	2.7

No stimulation; eccentric results.

TABLE XIV (*i*)

Bean roots grown in well water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Cu p.p.m.	Elongation 48 hrs.
check	2. mm.	.1	6. mm.
.05	6.	.5	.8

Showing stimulation at .05 to .1 p.p.m.

TABLE XIV (*j*)

Bean roots grown in distilled water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Cu p.p.m.	Elongation 48 hrs.
check	3. mm.	.1	3.1 mm.
.01	3.	.3	1.6
.05	3.7		

Showing no stimulation.

TABLE XIV (*k*)

Squash roots grown in well water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Cu p.p.m.	Elongation 48 hrs.
check	2.4 mm.	.1	5.7 mm.
.05	4.9	.5	.4

Showing stimulation at .05 to .1 p.p.m.

TABLE XIV (*l*)

Squash roots grown in distilled water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Cu p.p.m.	Elongation 48 hrs.
check	3.3 mm.	.05	3.1 mm.
.01	3.3	.1	2.1

Showing no stimulation.

TABLE XIV (*m*)

Bean roots grown in distilled water with $CuSO_4$

Cu p.p.m.	Elongation 48 hrs.	Height of tops
.1	2.9 mm.	87 mm.
.3	1.2	91
.5	.6	85

Bean roots grown in distilled water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Height of tops
.1	2.9 mm.	98 mm.
.3	1.	88
.5	.6	84

Showing same behavior with $CuSO_4$ and $Cu(OH)_2.CuCO_3$.

TABLE XIV (*n*)

Squash roots grown in distilled water with $CuSO_4$

Cu p.p.m.	Elongation 24 hrs.	Cu p.p.m.	Elongation 24 hrs.
check	3.6 mm.	.05	1.4 mm.
.01	2.8	.1	2.

Squash roots grown in distilled water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 24 hrs.	Cu p.p.m.	Elongation 24 hrs.
check	3.6 mm.	.05	1.1 mm.
.01	3.8	.1	.4

Doubtful stimulation at .01 p.p.m.

TABLE XIV (*o*)

Corn roots grown in distilled water with $CuSO_4$

Cu p.p.m.	Elongation 48 hrs.	Cu p.p.m.	Elongation 48 hrs.
check	8.7 mm.	.05	4.7 mm.
.01	10.9	.1	1.5

Corn roots grown in distilled water with $Cu(OH)_2.CuCO_3$

Cu p.p.m.	Elongation 48 hrs.	Cu p.p.m.	Elongation 48 hrs.
check	8.7 mm.	.05	3.3 mm.
.01	13.2	.1	2.

These cultures, while somewhat fragmentary, afford excellent indications of stimulating effects upon plant roots. Excluding squash, which is not satisfactory material to work with, corn and beans show consistent stimulations at very high dilutions. Measurements in all cases are averages of about ten observations.

TABLE XV

SUMMARY OF STIMULATION EFFECTS

Experiment	Culture	Copper salt used	Character and strength in copper of solution producing stimulation	
			Well water[6]	Distilled water
a	Corn roots	$Cu(OH)_2.CuCO_3$	at .01 p.p.m.	
b	Bean roots	$Cu(OH)_2.CuCO_3$	.03	
c	Corn roots	$Cu(OH)_2.CuCO_3$	.03	
e	Bean roots	$Cu(OH)_2.CuCO_3$	.05	
g	Corn roots	$Cu(OH)_2.CuCO_3$	.01–.1	
h	Corn roots	$Cu(OH)_2.CuCO_3$		none at .01 or above
i	Bean roots	$Cu(OH)_2.CuCO_3$	.05–.1	
j	Bean roots	$Cu(OH)_2.CuCO_3$		none at .01 or above
o	Corn roots	$CuSO_4$		.01
o	Corn roots	$Cu(OH)_2.CuCO_3$		.01

Only at very high dilutions (one part of copper to from 10,000,000 to 100,000,000 of water) are accelerations of root growth observed. These occur with both corn and beans, in well water. In distilled water stimulation was observed only at the highest dilution—1:100,000,000. In well water stimulation was observed at from 1:100,000,000 to 1:10,000,000—consistently with the well known fact that in presence of other soluble salts the effects of copper are lessened.

EFFECTS OF SOIL UPON TOXICITY OF COPPER SOLUTIONS

Of prime importance in connection with possible toxic effects of copper in soils are the various reactions (1) converting insoluble into soluble compounds, (2) reconverting these again into insoluble combinations, and (3) modifying the toxic effects of copper salts in solution.

As shown in the table of solubilities, both basic carbonate of copper and chrysocolla are soluble in carbon dioxide, forming solutions which in water cultures are highly toxic in character. Sulphides of copper are first oxidized to the sulphate, which is easily soluble:

$$Cu_2S + 5O = CuSO_4 + CuO$$

For instance, 100 grams of chalcocite ore containing 3.2 per cent copper were shaken in a flask with 600 c.c. of water, frequently, during twenty-eight days. At the end of that time 500 c.c. of solution contained 0.0132 grams of copper.

Copper sulphate then reacts in the soil to form various insoluble compounds with consequent lessening of toxic action. With calcium carbonate the following represents a reaction which may occur:

$$2\,CuSO_4 + 2\,CaCO_3 + H_2O = Cu(OH)_2.CuCO_3 + 2\,CaSO_4 + CO_2$$

For instance, two grams of precipitated carbonate of lime were added to an excess of ten grams of copper sulphate in one liter

[6] "University of Arizona well water" contains 250 p.p.m. of soluble solids, mainly sodium sulphate.

of water, and digested with frequent shaking for over four months, the green precipitate being then filtered off, dried and analyzed for copper:

Weight of precipitate taken	100.00 mg.
Cu found	47.85
Theoretical Cu in basic carbonate	57.38

Indicating by the formula above a conversion to basic carbonate of copper of over 83 per cent of the solid carbonate of lime present. Bicarbonate of lime in solution also reacts with copper sulphate to form the basic carbonate

$$CaH_2(CO_3)_2 + 4\,CuSO_4.5\,H_2O = 2\,Cu(OH)_2.CuCO_3 + CaSO_4 + 3\,H_2SO_4 + 16\,H_2O$$

$$3\,CaH_2(CO_3)_2 + 3\,H_2SO_4 = 3\,CaSO_4 + 6\,H_2O + 6\,CO_2$$

The silicates of the soil, also, and particularly those of zeolitic character, react readily with soluble copper compounds to form insoluble copper silicates. Organic matter likewise combines with large amounts of copper, to form compounds of indefinite or unknown composition. As a result of all these reactions, when soils are shaken up with solutions of copper salts the latter are withdrawn from solution in large amount. Under irrigation conditions, where waters containing minute amounts of copper are filtered through relatively large masses of soil, this action is nearly or quite complete.

Five large percolators were arranged with varying depths of

TABLE XVI

PERCOLATION OF COPPER SOLUTIONS THROUGH SOILS

		Solution used			
Soil	Depth	Cu compound	Cu in solution, p.p.m.	Amount of percolate, c.c.	Copper in percolate, p.p.m.
Sandy loam	1 in.	$Cu(OH)_2.CuCO_3$ in CO_2 water	95	2000	none
Sandy loam	5 in.	$Cu(OH)_2.CuCO_3$ in CO_2 water	95	1500	none
Sandy loam	9 in.	$Cu(OH)_2.CuCO_3$ in CO_2 water	95	2000	none
Sandy loam	1 in.	$Cu(OH)_2.CuCO_3$ in CO_2 water	56	2000	.85
Heavy clay containing .003% Cu	12 in.	$Cu(OH)_2.CuCO_3$ in CO_2 water	8.5	600	
Heavy clay containing .003% Cu	12 in.	$CuSO_4.5\,H_2O$	254	150	7.3

soil resting on filter paper supported by a perforated porcelain plate. Two soils, heavy clay and sandy loam, were employed; and two copper solutions, sulphate and bicarbonate.

In nearly all cases copper as basic carbonate was entirely removed from solution in percolating through as little as a single inch of sandy loam. Although appreciable amounts of copper sulphate passed out of a soil, the latter in that case itself contained a very small percentage of copper. Inasmuch as soluble copper in irrigating waters must be present ordinarily as basic carbonate, its complete withdrawal by thin layers of soil is significant in connection with irrigated crops.

Irrigation Experiments

A set of cultures was arranged to test the effects upon crop plants of solutions of basic copper carbonate so applied as to filter through the soil before reaching the plant roots. Six-inch

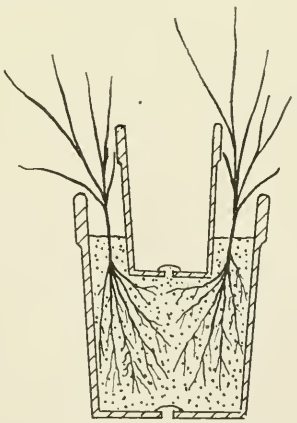

Fig. 5.—Diagram of pot culture irrigated through two-inch pot inside.

flower-pots were filled with sandy loam soil. In the middle of each of these pots a two-inch pot was half buried, and the plants experimented with were grown in the circles of soil between the large and small pots. These plants were irrigated by pouring the solution used into the small pot, through the bottom of which it passed, necessarily filtering through more or less soil before

reaching the plant roots. Radishes, beans, cantaloupes, cucumbers, lettuce, peas, beets, corn, berseem, avas, onions, barley, and wheat were employed; corn, barley, and wheat being especially successful under these conditions. All cultures were in pairs, one of each pair being irrigated with solutions of basic carbonate of copper in CO_2-water, and the check cultures with water only. In all other particulars—original strength of plants, exposure to light and air, and amount and time of watering—the conditions were identical.

These cultures were carried on in a greenhouse set aside for the purpose. The experiment was begun in November and ended the following March. The solutions of basic carbonate of copper employed contained from 0 to 55 p.p.m. of copper, averaging about 20 parts, which is from 7 to 670 times as much as has been observed in the waters of the Gila River from time to time.

TABLE XVII

CONDITION AT MATURITY OF CULTURES IRRIGATED WITH COPPER SOLUTIONS, AS COMPARED WITH THOSE IRRIGATED WITH WATER

C, copper culture; W, check.

		Tops	Roots
Radishes		C and W. The same in appearance and weight	The same, but in C roots were removed $\frac{1}{8}$ in. from inner pot hole
Beans	C greener	C and W. About the same	Equal; same number of nodules; very local effect of Cu at pot hole
Lettuce		C and W. About the same	The same except that in C roots were dead $\frac{3}{4} \times \frac{1}{8}$ in. under pot hole
Peas		C and W. Averaging the same	Both C and W having abundant nodules.
Beets			No apparent damage by Cu
Corn	Stimulated? C showing stronger	Weighing the same, but C appearing stronger	Fewer in soil under pot hole in C, otherwise equal
Berseem	C stimulated, earlier bloom	C more advanced in growth, but not so heavy	Equally developed, both showing strong nodule development.

		Tops	Roots
Avas		C and W. Same apparent growth	In C roots within ¼ in. of pot hole damaged. Both C and W show strong nodule development
Onions		C and W. Same general appearance	Very little local effect of Cu just under inner pot hole in C
Barley	C stimulated, matured over twice as much grain	The same in weight, but C matured more grain	No roots in C for space of 1 × ⅜ in. under inner pot hole
Wheat	C stimulated matured 20% more grain	Identical appearance, but C matured more grain	In C no roots under inner pot hole for space of 1¼ × ½ in.

In practically all cases a distinct but very local effect of copper solutions upon plant roots under the inner pot hole was observed. For a distance of a half-inch or less from the small pot hole exposed roots were dead or missing. The soil in this area was observed in two instances to contain 0.25 and 0.45 per cent copper, respectively. In one instance 80 per cent of the copper added was found in the 43 grams of soil just under the bottom of the little pot, showing the rapidity with which copper is removed from its solutions by filtration through the soil.

The tops of the cultures under consideration in no instance showed injury, but in certain cases were in a distinctly advanced condition. The amounts of copper contained in material derived from these cultures are as follows:

TABLE XVII (*a*)

COPPER CONTENT OF PLANTS IRRIGATED WITH COPPER SOLUTIONS

Sample No.		Dry matter, grams	Cu grams	P.p.m. of Cu in dry material
3673	Wheat and barley tops grown in check			
3675	soil containing a trace (.0025 per cent) of copper	32.90	.000100	3.04
3672	Tops of beans, peas, corn, lettuce, carrots, cucumbers and avas grown in check soil	133.00	.000350	2.60

Sample No.		Dry matter, grams	Cu grams	P.p.m. of Cu in dry material
3674 3676	Tops of wheat and barley irrigated with water averaging 20 p.p.m. copper	30.70	.000400	13.00
	Tops of beans, berseem, peas, onions, lettuce, beets, radishes, corn, avas, barley, and wheat irrigated with water averaging 20 p.p.m. copper	27.20	.000751	27.60
3690	Roots of same (washed in 4 per cent HCl)	8.30	.000750	90.00

In brief, even when relatively large amounts of water containing excessive quantities of soluble copper were applied and the experiments so arranged that all of the copper remained in the limited volumes of soil employed, no general injury to the plants was observed, although apparently slight stimulation occurred in some cases. Prolonged irrigation with such solutions would be required to saturate the soil to a depth sufficient to seriously injure plants grown in it.

Fig. 6.—Wheat and barley irrigated (C) with copper solutions filtered through soil, and (W) with well water. Both show stimulated growth with copper.

CULTURAL EXPERIMENTS

Pot Cultures with Treated Soils

Pot cultures of corn, beans, and squash were also grown in soils containing copper in the form of precipitated carbonate ($Cu(OH)_2.CuCO_3$), finely powdered (100-mesh) chalcocite or sulphide ore, and finely powdered chrysocolla or silicate ore. Large glazed stone jars containing thirty-eight pounds of soil were used. Effects on growth were observed and the copper content of tops and of root systems was determined. The following tabulations relate to the work done in this direction, the statement showing the copper content of corn, bean, and squash plants expressed in parts per million of copper in dry matter.

TABLE XVIII

Copper Carbonate Series (1908), Beans

Sample No.	Culture	Cu in soil, per cent	Appearance and height of plants	Dry matter, grams	Cu found, grams	Cu p.p.m. in tops	Cu p.p.m. in roots
			Normal				
3944	Beans	Check*	39 in.	16.6	.00022	13	
4013	Beans	Check*		.72	.00033		453
3945	Beans	.01	38	17.2	.00027	16	
4014	Beans	.01		1.35	.00116		859
3946	Beans	.025	39	15.9	.00033	21	
4015	Beans	.025		1.21	.00115		950
Toxic effects begin at about .035% Cu in soil.							
			Stunted				
3947	Beans	.05	30	13.2	.00031	23	
4016	Beans	.05		1.09	.00148		1358
3948	Beans	.1	25	6.7	.00011	16	
4017	Beans	.1		1.44	.00212		1472
3949	Beans	.25	14	3.7	.00009	25	
4018	Beans	.25		1.35	.00243		1800
3950	Beans	.5	15	2.9	.0001	35	
4019	Beans			.87	.00147		1690
3951	Beans	1.	12	2.2	.00009	41	
4020	Beans	1.		.53	.00106		2000
3952	Beans	1.5	14	2.1	.00009	44	
4021	Beans	1.5		.5	.00115		2300

* Containing traces of copper, .0025%.

Fig. 7.—Bean cultures grown in soils containing copper as precipitated carbonate, from none to 1.5 per cent Cu.

TABLE XIX

COPPER CARBONATE SERIES (1907), CORN

Sample No.	Culture	Cu in soil, per cent	Dry matter, grams	Cu found, grams	Cu p.p.m. in tops	Cu p.p.m. in roots
3870	Corn	Check*	45.2	.00020	4.40	
3885	Corn	Check*	8.8	.00035		40.00
3869	Corn	.01	175.9	.00115	6.50	
3868	Corn	.01	10.6	.00161		152.00
3865	Corn	.025	77.0	.00160	21.00	
3866	Corn	.025	9.2	.00670		728.00
3864	Corn	.05	47.7	.00103	22.00	
3867	Corn	.05	4.4	.00328		745.00
3863	Corn	.10	26.8	.00079	30.00	
3862	Corn	.15	9.8	.00046	47.00	
3861	Corn	.20	14.4	.00073	51.00	
3860	Corn	.30	4.6	.00110	239.00	

*Containing traces of copper, .0025%.

Fig. 8.—Corn cultures grown in soils containing copper as precipitated carbonate, from none to .2 per cent Cu.

COPPER CARBONATE SERIES (1908), CORN

Sample No.	Culture	Cu in soil, per cent	Appearance and height of plants	Dry matter, grams	Cu found, grams	Cu p.p.m. in roots
			Normal			
3992	Corn	Check*	43 in.	7.48	.00058	78.00
3993	Corn	.01	41	2.35	.00049	209.00
3994	Corn	.015	35	4.07	.00171	420.00
3995	Corn	.02	41	5.31	.00397	748.00
Toxic effects begin at about .023% Cu in soil.						
			Stunted			
3996	Corn	.025	33 in.	4.81	.00245	509.00
3997	Corn	.05	15	.31	.00023	742.00
3998	Corn	.10	22	3.62	.00651	1798.00
4000	Corn	.20	20	1.99	.00444	2231.00

* Containing traces of copper, .0025%.

COPPER CARBONATE SERIES (1908), SQUASH

Sample No.	Culture	Cu in soil, per cent	Appearance and height of plants	Dry matter, grams	Cu found, grams	Cu p.p.m. in tops	Cu p.p.m. in roots
			Normal				
3937	Squash	Check*	16 in.	11.2	.00016	14.00	
3938	Squash	.01	16	6.3	.00023	36.00	
3939	Squash	.025	15	9.2	.00031	39.00	
4026	Squash	Chk., .01, and .025		.24	.00004		169.00
Toxic effects begin at about .035% Cu in soil.							
			Blanched and stunted				
3940	Squash	.05	11 in.	3.7	.00017	46.00	
3941	Squash	.10	11	2.3	.00014	61.00	

Fig. 9.—Corn cultures grown in soils containing copper as sulphide (chalcocite), from none to 1. per cent Cu.

TABLE XX

CHALCOCITE SERIES (1908)

Sample No.	Culture	Cu in soil, per cent	Appearance and height of plants	Dry matter, grams	Cu found, grams	Cu p.p.m. in tops	Cu p.p.m. in roots
			Normal				
3979	Corn	Check*	36 in.	17.60	.00026	15.00	
3979c	Corn	Check*		4.62	.00027		58.00
3980	Corn	.01	33	11.60	.00011	10.00	
3980c	Corn	.01		2.94	.00023		78.00
3981	Corn	.02	38	19.40	.00021	11.00	
3981c	Corn	.02		6.14	.00114		186.00
3982	Corn	.03	35	17.90	.00028	16.00	
3982c	Corn	.03		6.99	.00176		252.00
3968	Corn	.05	45	51.70	.00065	13.00	
3978	Corn	.05		6.14	.00105		171.00
Toxic effects begin at about .08% Cu in soil.							
			Stunted				
3983	Corn	.10	36 in.	14.00	.00031	22.00	
3983c	Corn	.10	yellow	6.08	.00625		1028.00
3984	Corn	.50	8 in.	3.20	.00040	125.00	
3984c	Corn	.50		.47	.00065		1383.00
3985	Corn	1.00	12	3.20	.00050	159.00	
3985c	Corn	1.00		.49	.00089		1816.00

* Containing traces of copper, .0025%.

The cultures described in the foregoing tables indicate several interesting facts more or less applicable to field conditions.

(1) Precipitated carbonate of copper is shown to have a much more toxic effect upon corn than the finely pulverized ores of chalcocite or chrysocolla. With the precipitated carbonate 0.025 per cent in the soil was distinctly toxic, while with chalcocite and chrysocolla about 0.08 per cent was required to produce an equal effect. Inasmuch as all of these combinations of copper may occur in a soil subject to mining detritus, a mere determination of total copper in soils containing doubtfully toxic quantities cannot convey trustworthy information as to the injuriousness of the amounts present.

Moreover, since it has been shown that in the case of precipitated carbonate, and sulphate of copper, equivalent quantities of these salts in solution are equally toxic, it is probable that the greater toxicity of the carbonate is due to its greater solubility under soil conditions. It is, in fact, shown in table I, "Solubili-

TABLE XXI

CHRYSOCOLLA SERIES (1908)

Sample No.	grams	Cu in soil, per cent	Appearance and height of plants	Dry matter, grams	Cu found, Culture	Cu p.p.m. in roots	Cu p.p.m. in tops
			Normal				
4003	Corn	Check*	32 in.	25.60	.00025	10.00	
4003c	Corn	Check*		6.46	.00012		19.00
4004	Corn	.05	33	23.50	.00026	11.00	
4004c	Corn	.05		6.70	.00062		93.00
Toxic effects begin at about .08% Cu in soil.							
			Dwarfed				
4005	Corn	.10	30 in.	17.90	.00024	13.00	
4005c	Corn	.10	striped	5.82	.00094		162.00
4006	Corn	.10	28 in.	10.50	.00017	16.00	
4006c	Corn	1.00	yellow	4.29	.00233		543.00

* Containing traces of copper, .0025%.

Fig. 10.—Corn cultures grown in soils containing copper as silicate (chrysocolla), from none to 1. per cent Cu.

ties of Copper Compounds," that precipitated copper carbonate is soluble to the extent of 1.5 parts in 1,000,000 of water, while copper sulphide is soluble to the extent of 0.09 parts of copper in 1,000,000 of water. It is most probable, also, that the finely divided condition of the precipitated carbonate is more favorable to solution, and also to reaction with the acids of plant roots.

(2) Corn is seen to be distinctly more sensitive to the carbonate of copper than either beans or squash. With corn, toxic effects appear with 0.02 per cent of copper in the soil, while with beans and squash these toxic effects do not appear until 0.035 per cent of copper in the soil is reached. As is suggested

in the following pages, the physical constitution of root systems may account in part for varying degrees of sensitiveness to copper compounds.

The presence of copper in tops and roots of check is due to 0.0025 per cent of copper in the soil which was supposed originally to be free from this element.

POT CULTURES WITH FIELD SOILS

Two field soils containing copper from irrigating waters were tested in pot culture with reference to toxic effects and

Fig. 11.—Pot cultures of corn in field soils containing tailings. No. 3887, .027% Cu; no. 3888, .047% Cu; and no copper. Cultures in field soils are slightly affected.

copper content of root systems. The soils employed were from a field showing varying effects of accumulations of tailings, immediately southeast of Safford:

	Sample	Cu in soil, per cent
3887	Sandy loam, surface 12 in. of soil recently put under irrigation	.027
3888	Heavy clay (tailings) mixed with sandy loam, surface 12 in., long under irrigation, much tailings	.047

In these two soils, differing mainly through the addition of tailings to No. 3888, cultures of corn, beans, and squash were made, and examined for copper with the following results:

TABLE XXII

CULTURES IN TAILINGS SOILS

No.	Pot culture	Condition	Cu in soil, per cent	Cu p.p.m. in tops	Cu p.p.m. in roots
3887	Corn in sandy loam	Distinctly striped	.027		453.00
3888	Corn in sandy loam and tailings	Less distinctly striped	.047		163.00
3887	Beans in sandy loam	Normal appearance	.027	28.00	1523.00
3888	Beans in sandy loam and tailings	Normal appearance	.047	19.00	703.00
3887	Squash in sandy loam	Yellow and stunted	.027	73.00	
3888	Squash in sandy loam and tailings	Normal appearance	.047	45.00	

Fig. 12.—Showing effects of copper modified by tilth of soil. Strong growth, lumpy mixture; weak growth, thoroughly mixed.

Bean cultures appeared little affected by copper in either No. 3887 or No. 3888; but squash was distinctly damaged in No. 3887, being yellow and stunted. The leaves of both cultures of corn were paler than those of the check, but in soil No. 3887, containing less copper, the leaves of corn were more distinctly striped than in No. 3888. This is probably due to the sandy character of No. 3887 with consequently decreased adsorptive action upon copper salts. Lumpiness in the heavier soil might also account for a lessened toxic action, as indicated by an experiment in which 0.1 per cent of copper in the form of pre-

cipitated carbonate was mixed (1) intimately and (2) in lumpy condition. Results were as follows:

Sample No.	Cu as pptd. carbonate, per cent	Condition	Cu p.p.m. in roots
3998c	0.1 well mixed	22 in. high, much blanched	1798.00
3999c	0.1 lumpy	28 in. high, mostly green	457.00

In these instances it may be noted that toxic effects are associated with higher copper content of roots of plants, rather than with copper content of soils employed.

As in other cultures it is observed that beans, though carrying a higher copper content than corn, show less toxic effects—a fact possibly to be explained by the higher protein content of the plant with a consequently greater capacity for absorption of copper before toxic effects appear.

POT AND PLOT CULTURES

In order to carry experimental cultures further towards field conditions, cultures of wheat and corn in small plots of sandy loam garden soil, 2½ × 18 feet, were grown, copper in the form of finely powdered sulphate having been thoroughly spaded in four times to a depth of nine inches in the amounts shown in table XXIII. The roots of these cultures were harvested and examined as usual for copper.

TABLE XXIII

CORN GROWN IN GARDEN PLOTS CONTAINING Cu APPLIED AS $CuSO_4$ (1914)

Sample No.	Cu added, per cent	Condition of leaves	Dry matter, grams	Cu found, grams	Cu p.p.m. roots
5858*a*	none	Solid green	11.0	.00015	14.00*
Toxic effects begin at about .008% Cu in soil.					
5859*a*	.01	Distinctly yellow striped	11.6	.00117	101.00
5860*a*	.025	Distinctly yellow striped	8.6	.00211	246.00
5861*a*	.05	Distinctly yellow striped	7.3	.00215	296.00
5862*a*	.10	Strongly yellow striped	4.3	.00300	698.00
5863*a*	none		6.2	.00013	21.00*

* Probably resulting from roots spreading to copper soils.

TABLE XXIV

WHEAT GROWN IN GARDEN PLOTS CONTAINING Cu AS $CuSO_4$ (1914)

Sample No.	Cu added, per cent	Condition of leaves	Dry matter, grams	Cu found, grams	Cu p.p.m. in roots
5648*a*	none	29 in. high; good	4.46	.00012	27.00
5649*a*	.01	29 in. high; good	3.16	.00190	601.00
Toxic effects begin at about .02% Cu in soil.					
5650*a*	.025	25-27 in. high; affected	3.23	.00260	805.00
5651*a*	.05	23 in. high; severely affected	1.90	.00330	1737.00
5652*a*	.10	20 in. high; very severely affected	1.33	.00200	1504.00

TABLE XXV

WHEAT GROWN IN POTS TO CHECK PLOTS CONTAINING Cu AS $CuSO_4$ (1914)

Sample No.	Cu added, per cent	Condition of leaves	Dry matter, grams	Cu found, grams	Cu p.p.m. in roots
5672*a*	.0025	Green; 27 in. high	1.51	.00007	46.00
Toxic effects begin at about .005% Cu in soil.					
5673*a*	.01	Yellowish; 23 in. high	1.96	.00035	179.00
5674*a*	.025	Yellow and stunted; 17 in. high	.84	.00030	357.00
5675*a*	.05	Yellow and stunted; 12 in. high	.52	.00031	593.00
5676*a*	.10	Yellow and stunted; 4-12 in. high	.30	.00044	1476.00

The corn series contains much smaller proportions of copper in the roots than either of the wheat series, a fact explained in part by the coarser roots of corn, which therefore have less absorptive surface in proportion to their weight. Wheat roots grown in plots show much more copper than pot samples, although the copper is much more toxic to the plants in pots than in plots, a contradiction not easily understood unless it be that other less favorable conditions of growth in pots were responsible for the backward condition of the plants.

FIELD SAMPLES OF SOILS AND VEGETATION

In order to relate, if possible, the experimental work detailed on previous pages to samples of field material, roots of barley, wheat, oats and corn, were collected in the district studied and the amounts of copper in them determined. The samples of bar-

TABLE XXVI

COPPER IN SOILS, AND IN ROOTS OF PLANTS GROWN IN FIELD SOILS CONTAINING MINING DETRITUS, NEAR SOLOMONVILLE AND SAFFORD (1914)

Jan. 3, 1909		Dry matter, grams	Cu found, grams	Cu p.p.m. in tops	Cu p.p.m. in roots
4008*a*	Barley tops selected for toxic effects from tailings soil (Wm. Gillespie), Solomonville, under Montezuma Canal	13.90	.00061	43.80	
4008*b*	Barley roots, ditto	2.70	.00160		592.50
4009*a*	Oat tops selected for toxic effects from field one mile west of Solomonville, under Montezuma Canal	28.30	.00121	42.70	
4009*b*	Oat roots, ditto	2.55	.00025		98.00

March, 1914		Dry matter, grams	Cu found, grams	Cu p.p.m. yellow	Cu p.p.m. green	Per cent Cu in soils shaken from roots	
5544*a*	Barley roots, yellow plants	3.78	.00037	98		.017	
5545*a*	Barley roots, green plants	2.33	.00290		124		.006
5546*a*	Barley roots, yellow plants	3.41	lost	.....			
5547*a*	Barley roots, green plants	3.80	.00047		123		
5548*a*	Wheat roots, yellow plants	1.40	.00044	314		.054	
5549*a*	Wheat roots, green plants	1.25	.00048		382		.014
5550*a*	Barley roots, less green plants	2.17	.00077	354			
5551*a*	Barley roots, stronger plants	3.34	.00110		329		
5552*a*	Oat roots, yellow plants	1.67	.00066	394		.050	
5553*a*	Oat roots, green plants	1.77	.00030		169		.039
5554*a*	Barley roots, yellow plants	1.38	.00057	411		.073	
5555*a*	Barley roots, green plants	1.42	.00041		289		.032
	Average			314	236	.048	.023
4010	Corn roots (1908) in tailings soil, Solomonville	16.12	.00097		60		
November, 1914							
5841*a*	Corn roots, tailings 9 in. deep	10.18	.00021		21		
5842*a*	Corn roots, tailings 8 in. deep	11.08	.00038		34		
5843*a*	Corn roots, old tailings	10.01	.00038		38		.055
5844*a*	Corn roots, tailings 6–12 in. deep	21.48	.00039		18		
5845*a*	Corn roots, old tailings	16.24	.00068		42		
5846*a*	Corn roots, old tailings	5.02	.00034		68		.105
5847*a*	Corn roots, old tailings	14.42	.00104		72		.040
				Average	42		

ley, wheat and oats were collected in sets of two in a place. One of each set was green, healthy growth, the other more or less yellow and unthrifty in appearance. The object of this method of sampling in soils found to contain small amounts of copper was, if possible, to relate unthrifty appearance of plants examined to copper found in roots and surrounding soil. Table 26 (p. 441) contains the results of the determinations made.

As may be expected under field conditions, which are more complex and variable than those of plot or pot cultures, these data are considerably contradictory. Roots of yellow barley, wheat and oat plants, for instance, in 5544*a* and 5548*a* contain less copper than roots of strong green plants grown alongside; although the average copper content (314 parts) of yellow and more or less unthrifty plants is seen to be greater than in green plants alongside (236 parts). So far as observed, the larger percentages of copper found in soils shaken from roots of the plants are always associated with yellow plants. The average copper content of soils from roots of yellow plants is 0.048 per cent, while that from green plants is 0.023 per cent. These observations indicate that in a general way the larger amounts of copper found in these field soils are associated with larger amounts of copper in root systems and with yellow color in young plants. The percentages of copper observed in the soil, ranging up to 0.073 per cent in one instance, is surprisingly high, but toxic effects must be qualified by the character of the compounds, soluble salts in the soil, and other factors noted on preceding pages.

Yellowness of foliage also may be due to other causes than copper. Among these are: (1) too much water, as in low places; (2) alkali accumulations; (3) cold weather; (4) too much nitrogen in improper form, as in some old barnyards; (5) too little available nitrogen, as on new ground; (6) shade, and (7) insect pests and plant diseases. Malnutrition from any cause, in fact, usually expresses itself in the yellow or striped appearance of the leaves of these crop plants. Such appearance, therefore, cannot be attributed to copper present in the soil, without exclusion of other causes and sufficient confirmatory evidence.

As in the case of plot and pot cultures, corn roots are ob-

served to contain much less copper than other grain roots grown in similar soils, a fact to be attributed to the coarse character of field samples of corn roots.

USE OF COPPER SULPHATE TO KILL MOSS IN IRRIGATING DITCHES

Clear irrigating water supplies, such as are derived from seepage and from wells, quickly become choked with mosses and algae in warm weather, entailing loss of water and expensive ditch cleaning. In order to test the application of copper to a running stream for the purpose of killing the growth of aquatic plants, an experiment was conducted, in October, 1906, upon the Flowing Wells ditch near Tucson, which at the time contained abundant aquatic growth.

A barrel of copper sulphate solution was prepared and placed at the head of the ditch. By means of a small outlet controlled by a stopcock, fifteen pounds per hour of $CuSO_4.5H_2O$ were added to the ditch flow, this amount being in the proportion of 1 part of copper to 100,000 of water. Most of the copper was immediately precipitated by the bicarbonate of lime present in the water; still more probably combined in insoluble form with the soil along the ditch; while the remainder acted with toxic effect upon the sensitive algae and the less sensitive mosses (*Potomogetons*) growing in the water. A short distance below the barrel, where algae and mosses, after twenty-five hours' exposure to copper, were brown and dead and breaking away from their points of attachment, .84 parts of copper in 1,000,000 of water remained in solution. Three miles below the barrel, where the mosses and algae were still plainly affected, traces only of dissolved copper were perceptible. A renewal of copper from point to point would therefore have been necessary in treating a long ditch by this method, which, however, proved too costly for adoption in the instance mentioned.[7]

It is of interest in this connection to note that in the early days of irrigation on the Gila River, mosses grew in such abundance in the clearer waters obtained from the river at that time,

[7] See Bibliography, p. 237, reference 32.

that considerable labor was required to keep the ditches clean. These mosses have now entirely disappeared from the upper canals, due in part to the turbid waters in which they will not grow, and in part, perhaps, to the dissolved copper from the mines.

PHYSIOLOGICAL OBSERVATIONS ON TOXIC EFFECTS OF COPPER SALTS

Quantitative Work

Citrus seedlings placed in copper sulphate solutions containing from 2.5 to 100 parts of copper in 1,000,000 of distilled water wilted in forty-eight hours, thus showing effects of toxicity. Root tips then all turned red with K_4FeCy_6. Red root-tips sectioned showed under low power red cells under bark and around center. Citrus, cucumber and bitter melilot roots grown in 10:1,000,000 copper solution all gave violet reaction with KOH, less delicate but more distinctive than K_4FeCy_6, since the purple biuret test indicates both copper and protein.

Cultures of wheat, peas, corn, beans, and other plants grown in soils containing from 0.005 to 0.1 per cent of copper in soil, gave only very doubtful root-tip reactions with K_4FeCy_6, although showing evident injury, especially in 0.1 per cent culture. There is an essential difference between water-culture roots *placed in* copper solutions and roots *grown in* soil. The first are killed by excess of copper salts contained; the second are yet living and growing resistantly in the soil.

A 0.1 per cent copper culture of corn, wheat, beans and cucumbers was washed out from the soil and gave superficial red coloration with K_4FeCy_6, but not internal. Living tissue is evidently inconsistent with sufficient amounts of copper to give a plain internal test. Therefore, the small amounts of copper known to be in poisoned but living root systems must be disseminated. It is, therefore, of interest to know the copper-protein ratio in poisoned but living root systems, such a ratio being more significant than the ratio of copper to the whole mass of root systems, which includes various proximate principles not concerned in copper fixation.

Two assembled samples of corn, radish, wheat, vetch and peas grown in soils containing 0.005 per cent and 0.05 per cent of copper were, therefore, very thoroughly washed out, copper determined, and nitrogen determined $\times$ 6¼ for protein. The amount of copper required to saturate vegetable protein was assumed at 11.7 per cent (14.655 per cent CuO)—the average of figures given in Mann's *Chemistry of the Proteids*, page 305

(1) Roots grown in .005% Cu in soil ..... .4739000 gm.
Cu .0105% ..... .0000498
N. 2.26% = Protein 14.125% ..... .0669400
Cu required for saturation of protein
.06694 gm. $\times$ 11.7% = .007832 gm. Cu for saturation
Per cent saturated = $\frac{.0000498}{.007832}$ = .637%

(2) Roots grown in .05% Cu in soil ..... .3561000 gm.
Cu .0322% ..... .0001147
N. 2.76% = Protein 17.25% ..... .0614900
Cu required for saturation of protein
.06149 gm. $\times$ 11.7% = .007194 gm. Cu for saturation
Per cent saturated = $\frac{.0001147}{.007194}$ = 1.594%

Summary:	Cu p.p.m. dry roots	Per cent saturation of protein with copper
(1) .005% Cu in soil	105	0.636
(2) .05% Cu in soil	322	1.594
Ratio (1) to (2)	3.07	2.51

In brief, 10 times as much copper in the soil resulted in 3 times as much copper in the entire root systems and 2.5 times as much in the protein of these root systems. This latter increase, however, is responsible for an increase in damage from almost nothing to very severe.

Further observations on the copper-protein saturation figure in roots grown in soil containing copper, were made on wheat and Canada peas, planted in pots containing soil mixed with varying percentages of copper in the form of precipitated basic carbonate. The pots contained 102 pounds of sandy loam, and were irrigated in a uniform manner from time to time as water was needed. Plantings were made January 3, 1916, and roots harvested May 15.

TABLE XXVII

OBSERVATIONS ON THE SATURATION WITH COPPER OF PROTEIN IN ROOTS GROWN IN SOIL TREATED WITH $Cu(OH)_2.CuCO_3$

Lab. No.	Copper in soil, per cent	Material	Weight of sample, grams	Weight of Cu in sample, grams	Protein in sample, grams	Cu required to saturate protein, grams, factor 11.7%	Percentage of saturation of protein with Cu
6396	.005	Wheat roots	2.4726	.00023	.1069	.0125	1.84
6397	.02	Wheat roots	4.0122	.00068	.1660	.0194	3.50
6398	.06	Wheat roots	2.2236	.00068	.1231	.0144	4.70
6399	.10	Wheat roots	2.4658	.00037	.1401	.0164	2.25
6401	.005	Canada pea roots	2.6275	.00085	.3936	.0461	1.85
6402	.02	Canada pea roots	2.3844	.00093	.3684	.0431	2.16
6403	.06	Canada pea roots	2.0056	.00053	.2657	.0311	1.70
6404	.10	Canada pea roots	2.2708	.00093	.3747	.0438	2.12

While the figures on saturation in the last column of the table vary without reference to the amount of copper in the soil and the degree of injury observed in the roots, yet they all show a very low ratio of copper found to copper required for saturation of protein present.

In both wheat and peas, injury was first shown at 0.02 per cent of copper in soil, increasing greatly with higher percentages. This injury, showing as a characteristic crinkly condition, is best seen in wheat and corn and has been observed in wheat roots grown in a soil containing as little as 0.017 per cent of copper.

A further quantitative study of copper effects on root systems was carried out in water culture with corn, wheat, and Canada peas. Paraffin (parowax) disks one-third of an inch thick and nine inches in diameter were employed, perforated with holes of suitable diameter by means of steel cork borers. These disks were supported on paraffin posts two and one-half inches high in four-quart deep graniteware pans containing the water culture solutions which were used. After soaking, the germinating seeds were planted in paraffin disks of suitable perforation and nutrient solution was then poured up to level of contact with seeds. At first tap-water was used; then a nutrient solution made up as follows:

KNO_3	1.0 gm.
$MgSO_4$	.05
NaCl	.5
$CaSO_4$	.5
$FeCl_3$	.04
Tap-water	1.0 liter

No phosphate was included because of its precipitating action on copper salts. After the cultures were about four weeks old they were changed to nutrient solutions containing small amounts of copper which was gradually increased from one to ten parts per million of solution. The solution was neutralized with normal H_2SO_4 (methyl orange indicator) to prevent precipitation of copper by dissolved carbonates. Following is a summary of the history of the cultures, each of which was increased to include several hundred plants:

WHEAT

Dec. 16 Planted in tap-water.
Dec. 24 Transferred to nutrient solution, one-third strength.
Jan. 8 Changed to nutrient solution, two-thirds strength.
Jan. 14 To nutrient solution, full strength.
Jan. 17 To nutrient solution containing 1 part Cu per million.
Jan. 21 To nutrient solution containing 2 parts Cu per million.
Jan. 25 To nutrient solution containing 6 parts Cu per million.
Jan. 28 To nutrient solution containing 10 parts Cu per million.
Feb. 9 Experiment terminated.

A faint biuret test appeared after addition of 6 p.p.m. Cu. Also distinct K_4FeCy_6 test. Roots did not become flaccid, but the tops of cultures were dying back and prostrated markedly in comparison with roots of control culture.

CANADA PEAS

Dec. 20 Planted in tap-water.
Dec. 30 Transferred to fresh tap-water.
Jan. 6 Transferred to fresh tap-water.
Jan. 18 Transferred to nutrient solution.
Jan. 20 Changed to nutrient solution containing 1 part Cu per million.
Jan. 21 To nutrient solution containing 2 parts Cu per million.
Jan. 25 To nutrient solution containing 6 parts Cu per million.
Jan. 28 To nutrient solution containing 10 parts Cu per million.
Feb. 6-8 Experiment terminated.

A faint biuret test appeared after addition of 6 p.p.m. Cu. Distinct K_4FeCy_6 test in root tips at end of experiment. Roots not flaccid, but plants distinctly affected and tops dying back more than those of control culture.

CORN

Dec. 22 Planted in tap-water.
Jan. 8 Changed to nutrient solution, one-third strength.
Jan. 19 To nutrient solution containing 1 part Cu per million.
Jan. 21 To nutrient solution containing 2 parts Cu per million.
Jan. 25 To nutrient solution containing 6 parts Cu per million.
Jan. 28 To nutrient solution containing 10 parts Cu per million.
Feb. 9 Experiment terminated.

Giving distinct, faint biuret test after addition of 6 p.p.m. Cu; also K_4FeCy_6 test at end of experiment. Roots not flaccid at end of experiment, but tops of cultures about half dead, while tops of control culture were still in good condition.

These cultures, as shown by the notes, were exposed to copper solutions—wheat twenty-three days, peas eighteen days, corn twenty-one days. At the end of the experiment roots were not flaccid, but very faint biuret and distinct ferrocyanide tests were observed. In all cases top growth was affected, corn most, wheat next, and peas least. This material, as indicated above, is poisoned only just enough to show reactions in root tips, although tops are distinctly affected. It, therefore, represents minimum rather than maximum toxic conditions. Material was harvested and analyzed to show copper and nitrogen ratios; and by estimating the number of root tips in samples of corn, peas, and wheat the amount of copper per root tip, required to show faint tests, was found.

TABLE XXVIII

QUANTITATIVE DETERMINATIONS ON WATER CULTURES SHOWING SLIGHT TOXIC EFFECTS

CORN

No.	Sample	Dry matter, grams	Cu found, grams	Cu p.p.m. in dry matter
6321	265 tops	17.695	.00048	27.10
6320, 6323	Coarse roots	2.4277	.00022	91.00
6319	1100 root tips	.77	.00042	545.50

Amount of copper per root tip associated with slight toxic effects, $.00042 \div 1100 = .000000382$ gm.

PEAS

No.	Sample	Dry matter, grams	Cu found, grams	Cu p.p.m. in dry matter
6327	250 tops	7.0850	.00012	16.90
6325	Coarse roots	1.2827	.00180	1400.00
6326	Fine roots	.8393	.00141	1680.00
6324	5500 root tips	.4462	.00153	3428.00

Amount of copper per root tip required to show slight toxic effects, $.00153 \div 5500 = .000000278$ gm.

Total roots examined for nitrogen	4.41730 gms.
Albuminoids in roots (Alb. N. $\times$ 6¼)	.83929
Copper required to saturate albuminoids (factor 11.7%)	.09819
Total Cu found	.00784

Saturation $\frac{.00784}{.09819} = 7.99\%$

WHEAT

No.	Sample	Dry matter, grams	Cu found, grams	Cu p.p.m. in dry matter
6332	530 tops	12.7	.00165	129.90
6331	Roots	.6902	.00020	297.00
6330	16000 root tips	.3664	.00103	2811.00

Amount of copper per root tip associated with slight toxic effects, $.00103 \div 16000 = .000000064$ gm.

Total roots examined for nitrogen	2.9223 gms.
Albuminoids in roots (Alb. N. $\times$ 6¼)	.30794
Copper required to saturate albuminoids (factor 11.7%)	.03603
Total Cu found	.001789

Saturation $\frac{.001789}{.03603} = 4.96\%$

These figures show, as usual, relatively small amounts of copper in tops of plants, with large amounts in roots, increasing from coarser to finer portions, until in the root tips corn contains 545, peas 3428, and wheat 2811 parts per million of copper in dry matter. For peas and wheat these are the largest proportions of copper thus far observed in any plant samples.

When the total amount of copper found in each sample is divided by the number of root tips employed, an extraordinarily small amount of copper is found necessary to bring about toxic effects. For instance

One corn root tip (terminal 3 cm.) required....	.000000382 gms. Cu
One pea root tip (terminal 1 cm.) required.....	.000000278 gms. Cu
One wheat root tip (terminal 1 cm.) required	.000000064 gms. Cu

Moreover, the extent to which albuminoids in affected roots are saturated with copper—only 7.99 per cent for peas and 4.96 per cent for wheat—indicates a maximum effectiveness upon roots of small amounts of the metal.

REACTIONS OF COPPER WITH GROWING POINTS

Corn seedlings fifteen days old were fixed with cotton in tall 50-c.c. graduated Nessler tubes containing different strengths of copper sulphate in pure distilled water. The strengths of solution employed were 20, 10, 5, 2.5, and 1.25 p.p.m. There was a check culture with no copper. After three days, in all cases except the check, the roots were flaccid, showing contraction on graduations and giving biuret and ferrocyanide tests, increasing in strength from weaker to stronger concentration.

An experiment with pea seedlings gave similar results, but when the quantity of pea roots was increased and weak solutions, 2.5 and 1.25 p.p.m., were employed in small quantities (20 c.c.), the tests became much fainter.

Severed roots of corn, also, were observed to give as good tests as roots of living plants. A large number (seventy) of severed root tips placed in a small quantity (20 c.c.) of weak solution (5 p.p.m.) gave only a faint ferrocyanide test. These observations indicate that the concentration of copper in growing points is due to ionic dissociation and migration through the semi-permeable membranes of the root systems,[8] rather than to transpiration. The fainter test for copper in large quantities of root material indicates lessened toxicity of dilute solutions of copper in presence of excess of root materials.

Mature wheat, corn and pea plants in nutrient solutions, but not growing actively, were treated with gradually increasing amounts of copper from January 21 to February 2, as follows:

WHEAT, CORN, AND PEA PLANTS, THIRTY-SEVEN DAYS OLD, TREATED WITH COPPER IN NUTRIENT SOLUTION

Jan. 21–25; nutrient sol. w. 2 p.p.m. Cu.
Jan. 25–28; nutrient sol. w. 4 p.p.m. Cu.
Jan. 28 to Feb. 5, nutrient sol. w. 10 p.p.m. Cu.

[8] See Bibliography, p. 237, references 35, 36, 37, 38, 39, 40, 41, 42, 43, 44.

Feb. 5; very faint biuret test for copper, distinct ferrocyanide test.

Corn, forty-eight days old in 50 p.p.m. Cu sol., two days, gave faint biuret and ferrocyanide tests.

Corn, forty-eight days old in 500 p.p.m. Cu sol., two days, gave faint tests for copper.

From these observations it is evident that the nearly negative results shown are due either to nutrient salts present or to the older and therefore more quiescent material employed. To settle this question, the following experiments were made:

(1) Young (ten days) wheat and corn plants were placed in copper solution in distilled water and in nutrient solutions and observed after twenty and forty hours, as follows:

2.5 p.p.m. Cu, distilled water—20 hours

10 days old: Young wheat; flaccid?; strong biuret test; strong K_4FeCy_6 test
60 days old: Old wheat; not flaccid; no strong biuret test; distinct K_4FeCy_6 test
10 days old: Young corn; flaccid; strong biuret test; strong K_4FeCy_6 test
60 days old: Old corn; flaccid; no biuret test; old tips, faint K_4FeCy_6 test young tips, strong K_4FeCy_6 test

10 p.p.m. Cu, distilled water—20 hours

10 days old: Young wheat; flaccid?; strong biuret test; strong K_4FeCy_6 test
60 days old: Old wheat; not flaccid; faint biuret test; distinct K_4FeCy_6 test
10 days old: Young corn; flaccid; strong biuret test; strong K_4FeCy_6 test
60 days old: Old corn; flaccid?; distinct biuret test; strong K_4FeCy_6 test

40 p.p.m. Cu, distilled water—20 hours

10 days old: Young wheat; flaccid; strong biuret test; strong K_4FeCy_6 test
60 days old: Old wheat; flaccid?; faint biuret test; distinct K_4FeCy_6 test
10 days old: Young corn; flaccid; strong biuret test; very strong K_4FeCy_6 test
60 days old: Old corn; flaccid; strong biuret test; strong K_4FeCy_6 test

The above results indicate that old roots of corn and wheat are more resistant to the penetration of copper than are the young roots. This is shown by less flaccidity in the weaker solutions and by the fainter tests observed. A second series with greater strengths (5, 20, and 100 p.p.m.) and longer exposure (forty-five hours) showed distinctly less differentiation than in the case of the series above given in detail. This is to be expected, inasmuch as stronger solutions must overcome resistance of roots exposed to them more quickly, and the longer time employed would likewise tend to overcome differences existing in the first few hours of the experiment.

(2) Young and old wheat and corn roots were placed in 10 p.p.m. Cu in distilled water and 10 p.p.m. Cu in nutrient solution, with the following results:

10 p.p.m. Cu, distilled water—20 hours

10 days old: Young wheat; flaccid?; strong biuret test; strong K_4FeCy_6 test
60 days old: Old wheat; not flaccid; faint biuret test; distinct K_4FeCy_6 test
10 days old: Young corn; flaccid; strong biuret test; strong K_4FeCy_6 test
60 days old: Old corn; flaccid; distinct biuret test; strong K_4FeCy_6 test

10 p.p.m. Cu, neutralized nutrient solution—20 hours

10 days old: Young wheat; not flaccid; doubtful biuret test; faint K_4FeCy_6 test
60 days old: Old wheat; not flaccid; none or doubtful biuret test; faint K_4FeCy_6 test
10 days old: Young corn; not flaccid; faint biuret test; distinct K_4FeCy_6 test
60 days old: Old corn; not flaccid; distinct biuret test; distinct K_4FeCy_6 test

This shows very distinctly the prevention of toxic action upon plant roots through the protective action of other solids in solution, as already observed in water cultures by measurements of root growth. It is noteworthy in this connection that corn roots generally seem to be more sensitive to the action of copper salts than the roots of wheat or peas.

In order to examine still further into the relative resistance of old and young root systems to copper salts, a solution of 5 p.p.m. Cu in distilled water was used, the time being varied from twenty to two hundred hours. The results of these observations indicate that, with wheat and corn roots, the penetration of copper is distinctly more rapid in young than in old material. Peas did not give clear results.

It appears from these observations, first, that the accumulation of copper in plant roots is distinctly due to the migration of dissociated ions into the root systems, where they are fixed by protoplasm, in which combination they are identified by means of the biuret test. Second, the presence of nutrient salts very distinctly lessens the effect of a 10 p.p.m. copper solution upon sensitive young growing plant roots. Third, old quiescent plant roots developed in a nutrient solution are distinctly less sensitive to copper salts than young roots which are still actively growing.

The slow development of biuret tests for copper in such material after sufficient exposure to copper solutions, indicates the presence of protoplasm.

It is possible that the same observations may apply to other poisons, metallic or otherwise, brought into contact with absorp-

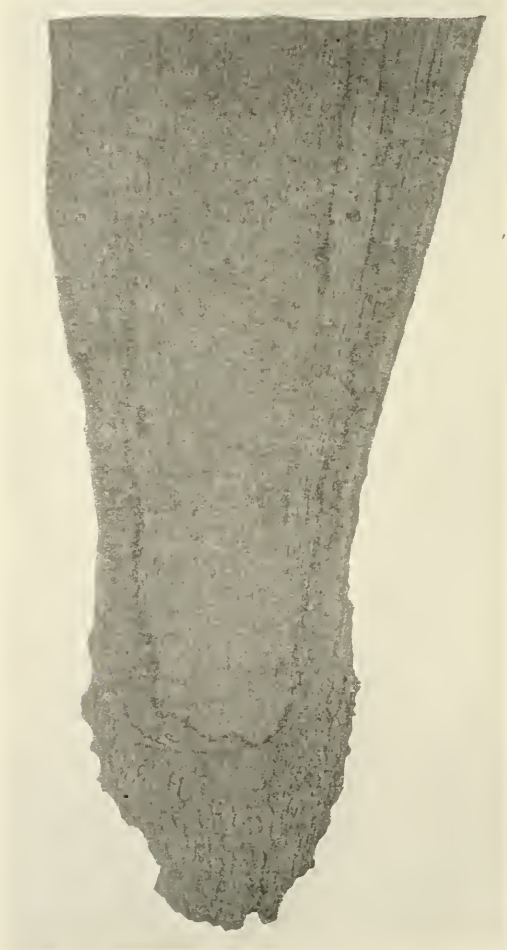

Fig. 13.—Photomicrograph of root tip of corn grown in water culture and poisoned by 1:200,000 of Cu in solution. The copper is shown as red copper ferrocyanide, which appears black in the photomicrograph. The irregular inner black line shows the penetration of the copper and also indicates sharply the differences in permeability of adjacent cells, some of which are penetrated before others. (× 80 diam.) (Photo by J. T. Barrett.)

tive root systems in the soil. Not only this, but it may be true that nutrient salts, as well, will be found more actively absorbed by younger and more sensitive root systems than by older ones, or by root systems which for any reason have become quiescent. This would suggest the possibility of choosing to advantage the proper time for applying substances, either to avoid injury or, as in the case of fertilizers, to secure maximum benefit from them.

Varying Resistance of Individual Cells to Copper

Not only do old and young roots vary as to toxic effects upon them of copper, but different degrees of resistance between individual cells in the same root and even in the same chain of cells, is clearly shown in the photomicrograph (fig. 13) of a corn root tip which has been exposed to a 1 to 200,000 solution of copper, then colored with K_4FeCy_6, and sectioned for observation. The dark, abruptly angular line of penetration shown in the section plainly indicates that individual cells may be penetrated by copper while adjacent cells growing under precisely similar physical conditions are not penetrated. If this be not due in some unseen way to morphological peculiarities of root structure, it must be due to individuality in the cells themselves, some of which must be more resistant to penetration by dilute copper solutions than others.

Summing up the physiological observations relating to effects of copper upon plants, we find (1) that individual cells vary (probably) in degree of resistance to penetration by copper salts; (2) that young roots are less resistant than old roots; (3) that roots of certain species of plants (e.g. corn) are less resistant than roots of other species; and (4) that toxic effects may be to some extent related to the structure and distribution of root systems.

DIAGNOSIS OF COPPER INJURY

In the presence of toxic amounts of copper in the soil, the root systems of culture plants become harsh and crinkly with almost entire loss of root hairs. Consistent with the checking of growing points, root systems are also greatly restricted in extent,

and in feeding capacity. Individual roots are coarse, covered with thick epidermis, and are abruptly angular, apparently as a result of chemotropic contortions Root tips are shortened and thickened and in some instances are strongly proliferated. The anatomical structures associated with these changes in form are very striking. In corn the cells of the primary cortex, in normal roots, are elongated parallel with the axis of the root, and in longitudinal tangential section measured about 74 by 30 microns. Injured cells of corn grown in soil containing 0.1 per cent copper gave longitudinal tangential sections approximately 34 by 30 microns, as shown on accompanying drawings. (See, also, plates II, III, and IV.

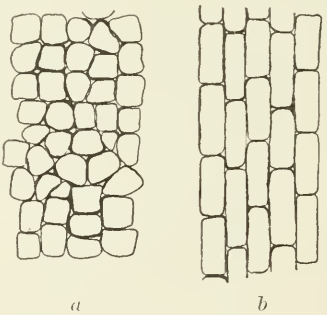

Fig. 14.—*a*. Tangential longitudinal section of corn root grown in soil containing .1 per cent of copper as copper sulphate, showing cells of cortex of injured rootlet. *b*. Tangential longitudinal section of normal corn root cells of cortex. (× ± 300 diam.) (Sections by G. F. Freeman.)

These structural modifications, taken in connection with other symptoms and conditions and in the absence of other causes, such as an excess of alkali salts,[9] confirm a diagnosis for copper injury in a soil of doubtful toxicity. For instance, March 4, 1916, two sets of samples of barley were collected in the district studied, and the material examined for evidence of copper injury, as follows:

Lot 1.—Young barley plants from the upper end of a field midway between Safford and Solomonville, under Montezuma Canal. The soil next the ditch shows old tailings, and there are irregular areas of yellow barley immediately under the canal.

[9] See Livingston, Botanical Gazette, vol. 30, no. 5, p. 229, 1900.

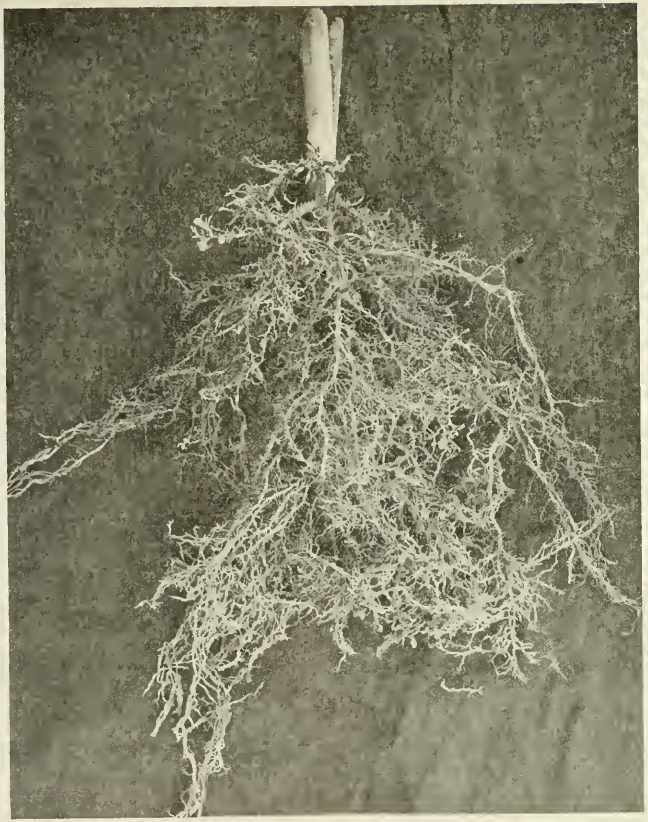

Fig. 1

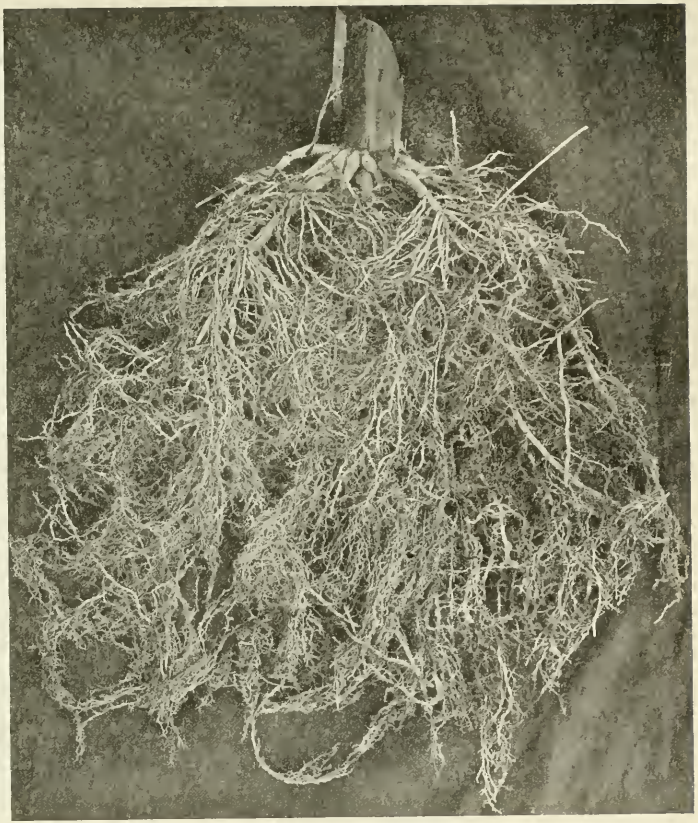

Fig. 2

PLATE II

Fig. 1.—Root system of corn plant injured by 0.1 per cent of copper added as copper sulphate to the soil.
Fig. 2.—Normal corn root grown in similar soil containing no copper. (Photos by G. F. Freeman.)

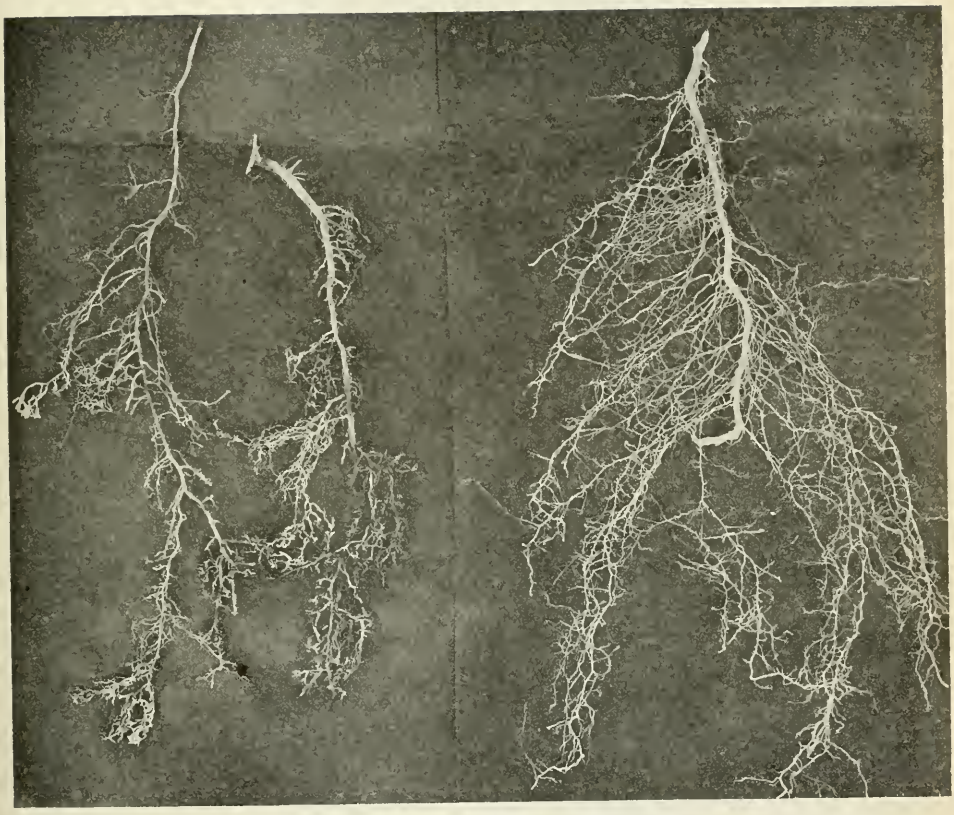

Fig. 1 Fig. 2

PLATE III

Fig. 1.—Individual roots of corn injured by 0.1 per cent of copper added as copper sulphate to the soil.

Fig. 2.—Individual root of corn, normal.

(Photos by G. F. Freeman.)

Fig. 1

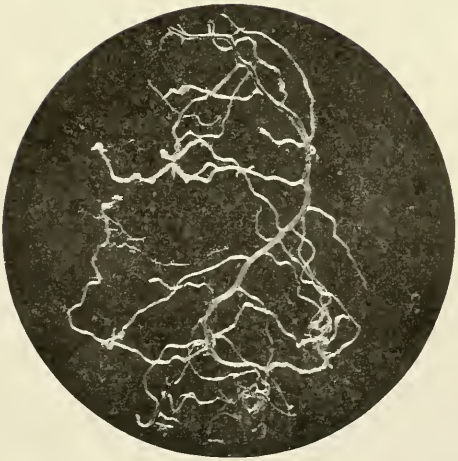

Fig. 2

PLATE IV

Fig. 1.—Thickened rootlets and proliferated root tips of corn injured by 0.1 per cent of copper added as copper sulphate to the soil. (× 3 diam.)

Fig. 2.—Fine roots and root tips of corn, normal. (× 3 diam.)
(Photos by G. F. Freeman.)

Sample No.	*a*. Yellow barley plants	
6343	Roots, crinkly and angular, much branched near surface. Dry weight, 3.2429 gms; Cu, .00085 gm; p.p.m.	262
6344	Soil shaken from yellow barley roots	
	Copper	.07979%
	Total soluble solids (alkali)	.46400
	Cl as NaCl	.004
	Sodium carbonate	.008
	Nitrogen	.137
	b. Green barley plants from near (*a*).	
6345	Roots, smooth and straight, not much branched near surface. Dry weight, 1.6025 gm; Cu, .0002 gm; p.p.m.	125
6346	Soil shaken from green barley roots	
	Copper	.05844%
	Total soluble solids (alkali)	.45600
	Cl as NaCl	.004
	Sodium carbonate	none
	Nitrogen	.181

Lot 2.—Young barley plants from the upper end of a field in West Layton under Montezuma Canal. Soil near ditch known to contain tailings and showing spots of yellow barley at head of field.

Sample No.	*a*. Yellow barley plants	
6347	Roots, crinkly and angular, much branched. Dry weight, 3.2977 gms; Cu, .0014 gm; p.p.m.	425
6348	Soil shaken from roots of yellow barley plants	
	Copper	.1113%
	Total soluble solids (alkali)	.50
	Cl as NaCl	.008
	Sodium carbonate	.008
	Nitrogen	.165
	b. Green barley plants from near (*a*)	
6349	Roots, smooth, straight, not much branched. Dry weight, 2.2473 gms; Cu, .0003 gm; p.p.m.	133
6350	Soil shaken from roots of green barley plants	
	Copper	.02678%
	Total soluble solids (alkali)	.40
	Cl as NaCl	.008
	Sodium carbonate	.004
	Nitrogen	.127

Considering the above observations, we notice that the soils from which samples were taken do not contain injurious amounts of soluble salts. Their nitrogen content, also, is normal. The areas of yellow barley from which samples come are therefore not to be attributed to alkali salts, or to abnormal nitrogen content. Observation in the field, also, failed to indicate that conditions of irrigation, temperature, or light were unfavorable, these conditions being the same for both green and yellow samples.

Excluding these considerations, therefore, we now find that there is uniformly more copper in the roots of yellow barley plants than in those of the green ones, also in the soils in which they occur. The roots of yellow plants, moreover, show the crinkly condition caused (though not exclusively) by copper when present in toxic amounts in the soil. The following statement summarizes these observations.

	Cu in soil per cent	Cu p.p.m. in roots	Condition of roots
		LOT 1	
Yellow barley	.0798	262.00	Crinkly and branched
Green barley	.0584	125.00	Straight, not branched
		LOT 2	
Yellow barley	.1113	425.00	Crinkly and branched
Green barley	.0268	133.00	Straight, not branched

The evidence therefore indicates quite conclusively that the two yellow samples owed their color to toxic effects of copper upon the roots of the young plants. Later in the season, however, no difference in mature plants, showing variations in color when young, may be observed. This must be due to the fact that as root systems penetrate more deeply into the soil they escape the surface zone of tailings, with consequent recovery from the effects of copper.

Part II.—GENERAL DISCUSSION

PRELIMINARY STATEMENT

The copper compounds, in solid form and in solution, that result from mining operations in the Clifton-Morenci district, have found their way down the San Francisco and Gila rivers to the underlying irrigated agricultural soils of Graham County in sufficient amounts to raise the question of their toxicity to crops. The largest amounts of copper in these soils are found at the heads of irrigated lands, especially where alfalfa is or has been, at which points old accumulations of tailings, laid down for the most part prior to 1908, are still to be found.

Accumulations of Copper

The amounts of copper accumulating in the Gila River valley soils in this way are small, the observed range being from 0.006 per cent to 0.111 per cent in surface soils and the average for eighteen soils analyzed being 0.046 per cent of copper. Irrigated soils elsewhere have been observed to contain larger quantities of copper than those above noted, for instance 1.002 per cent on the Deer Lodge River below Anaconda, Montana, with an average of 0.09 per cent for eleven other samples taken in the same locality.[10]

These amounts of copper in a soil may or may not be toxic according to the combination in which the copper exists, the physical character of the soil and its chemical composition, climatic and moisture conditions, the crop grown, and other considerations which may now be discussed in order.

The small amounts of soluble copper constantly coming down stream from the mines which cannot, like solid tailings, be entirely excluded from irrigating water supplies, are of importance because of their tendency to accumulate by reason of the fixing power for copper of silicates, carbonates and organic matter in the soil. The completeness of this fixing power of soil for copper is shown by several experiments in which solutions of copper

[10] U. S. D. A. Bur. Chem., Bull. 113, p. 34, 1907.

salts were percolated through one to twelve inches of soils, with little or no copper appearing in the filtrates. Under field conditions, therefore, this action tends to concentrate dissolved copper in irrigating water in the surface few inches of the soil.

A series of samples of Montezuma Canal water taken at Solomonville affords quantitative suggestions in this connection:

TABLE XXIX

COPPER CONTENT OF GILA RIVER WATERS

Sample No. and date		Description	Amounts of Cu added in irrigation, estimated in p.p.m. of water			Approx. flow of Gila River in sec. ft.	Approx. amts. of copper carried down stream, 1 day lb.
			In tailings	In solution	Total		
3309	May 26, '04	River very low	18.3	.80	19.1	30	3094
3486	June 11, '05	Small flood	.....	.25		170	230 (Soluble only)
3622	June 25, '06	River low	1.6	.11	1.71		
3737	Feb. 22, '07	Medium flood	trace	2.88	±3.0	600	9720
4011	Jan. 3, '08		2.1	.08	2.18		
		Tailings shut out of river May 1, 1908					
4029	Apr. 12, '09		1.4	.08	1.48		
6342	Mar. 4, '16*		.04	.03	.07		

* Following four-months shut-down of operations in Clifton-Morenci district.

These figures, while somewhat meagre, seem to indicate a lessening waste of copper downstream following the restraint of tailings from the water-supply in May, 1908. This is especially true of copper in solution, due probably to the decreased amounts of solid copper compounds in suspension from which copper in solution is derived.

Assuming at the present time an average of 1 part of copper in 1,000,000 of Gila River water, four acre-feet of such water, required for one year's irrigation, would contain 10.9 pounds of copper, from which should be deducted small losses due to vegetation, drainage waters, and percolation to depths below the surface soil.

Six tons of alfalfa with a copper content of 5 p.p.m. contain 0.06 lb. copper; while one acre-foot of seepage water (about the annual seepage loss) containing 0.25 p.p.m. copper would carry 0.68 lb. copper. Estimating the total loss roughly at one pound

of copper per acre a year, the net addition of copper to the soil would be approximately ten pounds, or about 0.00025 per cent. It would therefore require about forty years to accumulate 0.01 per cent of copper in the surface foot of soil. Inasmuch as, under field conditions, this is not an injurious amount, there is little likelihood, considering the district in a general way, that the small residues of copper now coming down stream will accumulate to an injurious extent within a reasonable period of time. Incidentally, it is of interest to note the large total losses of copper (3094 lb. and 9720 lb. per day observed) formerly resulting from mining operations in the district.

Possible Effects upon Health

With reference to the question of poisonous effects upon man and animals of dissolved copper in irrigating and well-waters, such effects, in general, are much less upon animals than upon plant life. Moore and Kellerman state, for instance, that 0.02 gms. of copper may be absorbed daily by a man with safety.[11] This amount of copper would be contained in five gallons of water containing one part per million of copper, the largest amount of copper observed in a well-water in the district studied being 0.53 p.p.m. It is of interest in this connection to note a belief of the copper miners of the Rio Tinto in southern Spain, where the wells are impregnated with copper, that one part of copper per million of drinking water is permissible, but that two parts per million result in "copper colic."[11a] In view of experiments upon human subjects, however, it is more than likely that deleterious effects observed are due to associated compounds in the water. It is of importance to note that a strength of as little as one part per million of copper in pure water will destroy algae, which are common in clear water supplies freely exposed to light and air. This fact may be made of use in cleaning ditches and reservoirs of aquatic growth, where the expense is not too great.

The germicidal effects of small amounts of copper in waters of the district studied also have a bearing upon human health.

[11] U. S. D. A. Bur. Pl. Ind., Bull. 64, p. 23.

[11a] Conversation of J. W. Bennie, Clifton, Arizona.

Bacilli of various species reacting upon human health are very sensitive to the action of soluble copper salts. For instance, in distilled water "one part copper in 16,000,000 parts water killed typhoid bacilli in two hours. In copper solutions made up with tap and sea water, the action was still marked, but less vigorous than in distilled water."[12] Moore and Kellerman state that one part of copper sulphate to 100,000 parts of water destroys typhoid and cholera germs in three to four hours.[13] In milk supplies as little as one part of copper salts in 2,000,000 of water acts as an antiseptic against putrescent bacteria.[14] It seems, therefore, that there is a possibility that the amounts of copper observed in ditch and well-waters in the district may have an antiseptic effect upon malignant germs, more particularly typhoid fever, likely to occur in the district.[15]

AMOUNTS AND SIGNIFICANCE OF COPPER IN AERIAL VEGETATION

The amounts of copper found in aerial parts of vegetation within the district are small, ranging from a trace to 7.6 parts copper in 1,000,000 of dry matter and averaging 3.41 parts. Miscellaneous cultures in water, potted soils, and plots gave larger amounts of copper which, however, were associated in most cases with toxic effects. Table 30 (p. 462) contains a summary of these data.

Even allowing for errors of method and of analysis, the European figures (3) seem excessively high, although the woody character of most of the samples was for the most part very different from that of the tender crop plants of the Arizona series.

Little can be said as to the toxic effects of the copper observed in aerial plant parts in the Arizona samples. The yellow striping of copper-poisoned corn is probably a general symptom of malnutrition to be attributed to the effect of copper upon root systems rather than upon leaves and stems. In rare instances, however, beans and squash in water culture showed dark green

[12] Biochem. Jour., Aug., 1908, pp. 319–323.

[13] U. S. D. A. Bur. Pl. Ind., Bull. 64, p. 43.

[14] Jour. Ind. and Eng. Chem., Sept., 1909, p. 676.

[15] See Bibliography, p. 236, references 3, 20, 21, 22.

TABLE XXX

Summary of Copper Content of Aerial Vegetation

	No. of samples	Min.	Max.	Ave.
		Parts per million copper		
1. Field vegetation from upper Gila	10	trace	7.60	3.41
Field vegetation from other sources in Arizona	9	none	6.30	1.52
2. Corn plants grown in pots .01–.05 per cent Cu	3	6.5	21.00	13.30
Tops of corn, beans and squash grown in Cu water culture	6	11.7	32.00	22.90
Tops of corn, beans, etc., irrigated with copper solutions				14.00
Beans in soils containing Cu	9	13.0	44.00	26.00
Squash ditto	5	14.0	61.00	39.00
Corn ditto	20	4.4	239.00	42.00
3. Field samples collected by Lehmann[16]	43	0	560.00	86.00
Field samples collected by Vedrödi[17]				
1894	26	40.0	1350.00	257.00
1895	26	10.0	680.00	151.00

patches that may possibly have been due to presence of copper, inasmuch as appearances of this character are sometimes noted as an effect of the application of Bordeaux mixture. Bain states, for instance, that extremely minute amounts of copper stimulate formation of chlorophyll in a cell, and therefore increase the formation of starch.[18] Ewart, also, shows that solutions of copper as dilute as 1 to 30,000,000 prevent the action of diastase upon starch.[19] It is possible, therefore, that the juices of plant tissues containing traces to 239 parts (observed) of copper in 1,000,000 of dry matter may carry sufficient of this amount in solution in the cell sap to hinder the action of enzymes upon starch, and thus prevent its normal translocation.

[16] *Der Kupfergehalt von Pflanzen und Thieren in Kupferreichen Gegenden,* Lehmann Archiv für Hygiene, vol. 27, pp. 1–17, 1896.

[17] Quoted in Brenchley, *Inorganic Plant Poisons,* p. 17, 1914.

[18] Bain, Tenn. Agr. Exp. Sta., vol. 15, Bull. 2, p. 93, 1902.

[19] Ewert, Zeitschr. für Pflanzenkrankh., vol. 14:3, p. 135, 1904.

AMOUNTS AND SIGNIFICANCE OF COPPER IN ROOT SYSTEMS

Of far more and unmistakable importance is the effect of copper on root systems of plants. Under all conditions, whether grown in water culture, in pots, plots, or as field crops, the root systems of plants contain much greater amounts of copper than do the aerial portions, as is shown briefly in the following condensation of results:

TABLE XXXI

SUMMARY OF COPPER CONTENT OF TOPS AND ROOTS OF PLANTS

	No. of samples	Cu in p.p.m. Tops	Cu in p.p.m. Roots	Ratio
Corn, beans, and squash in water cultures, poisoned but living	3	22.00	103.00	1 to 4.7
Ditto—killed by copper	3	23.00	268.00	1 to 11.6
Corn grown in soil containing .01 per cent of Cu as $Cu(OH)_2CuCO_3$	1	6.50	152.00	1 to 23
Corn grown in soil containing .025 per cent Cu as $Cu(OH)_2.CuCO_3$	1	21.00	728.00	1 to 35
Corn grown in soil containing .05 per cent Cu as Cu_2S	1	12.50	171.00	1 to 14
Bean series grown in soils containing Cu as pptd. carbonate .0025 to 1.5 per cent Cu in soil	9	26.00	1431.00	1 to 55
Corn series grown in soils containing Cu as Cu_2S .01 to 1 per cent Cu in soil	7	51.00	702.00	1 to 14
Corn series grown in soils containing Cu as chrysocolla, .05 to 1 per cent Cu in soil	3	13.00	266.00	1 to 20
Corn series grown in soils containing Cu as pptd. carbonate, .0025 to .05 per cent Cu in soil	4	13.00	416.00	1 to 32

Excluding samples grown in water cultures, the roots of which were cleaned with 4 per cent HCl, probably with loss of some copper, the root systems of experimental cultures contained averages of from fourteen to fifty-five times as much copper as the aerial portions of the plants. Furthermore, fine roots of corn were found in one instance to contain about three times as much copper as coarse roots of the same sample, and, finally, the maximum amount of copper, as determined both by analysis and by observation, in water cultures, was found in the root *tips*

of plants affected by copper. Analyses of water cultures of corn, peas, and wheat showing slight toxic effects gave the following ratios of copper in tops, root systems, and root tips:

Water cultures showing slight toxic effects	Cu in p.p.m.		
	Tops	Roots exclusive of tips	Root tips
Corn	27.00	91.00	545.00
Peas	17.00	1400.00	3428.00
		1680.00	
Wheat	130.00	297.00	2811.00

The root tips in this material, by means of caustic potash (the biuret reaction) and potassium ferrocyanide, show the characteristic purple and dark-red reactions due to copper. In the former case not only copper, but copper *in combination with proteids*, is indicated—the purple color being due to the biuret test, which identifies both copper and proteids simultaneously. In roots grown in water culture, and then subjected to the action of dilute copper solutions, the location of copper in a poisoned root system can be seen under a low power with considerable exactness. The purple of the biuret test begins very definitely with the growing point of the root tip and fades out gradually in comet-like fashion usually within one or two millimeters distance of the tip. New growing points in process of pushing their way through the epidermis along the sides of the roots likewise give a strong but very local biuret reaction. This combination of copper (in the form of oxide) and proteids is one used for the precipitation of albuminoid nitrogen in chemical analysis of feeding stuffs.[20] The amount of copper entering into the combination varies with proteids from various sources. As a rule, animal proteids combine with much less copper than vegetable proteids—averaging about 2.4 per cent of copper for egg albumin. Vegetable proteids combine with from 11.60 to 16.97 per cent of copper oxide and average 11.7 per cent copper.[21] Ordinarily, therefore, a vegetable proteid would be saturated with about one-ninth of its weight of copper; but its physiological activities are disarranged and the root killed by much less than the amount required to saturate the proteid.

[20] See Bibliography, p. 237, reference 48.

[21] Mann, Chemistry of the proteids, p. 305.

For instance, in samples of wheat and pea roots grown in water culture, it was found by means of nitrogen and copper determinations, using the factor 11.7 per cent copper for saturation of albuminoids, that in wheat roots 4.96 per cent of the copper required for saturation was present and in pea roots 7.99 per cent.

It appears, therefore, first, that copper attacks plant proteids at the most delicate and vulnerable points in the whole plant organization—the growing points of the root systems; and, second, that a small proportion of the copper required for complete reaction is sufficient to kill the protoplasm at these points. Again, it is to be observed that, especially in the seedling stages of growth, the number of growing points is small so that only extremely minute amounts of copper are required to arrest the growth of root tips, the spread of root systems and the nutrition of the plant.

Inasmuch, also, as plants vary greatly in the physical structure and the physiological activity of their root systems, including the number, delicacy and absorptiveness of their growing points, it is not unlikely that the varying sensitiveness to copper salts of different plants, and of the same plant at different ages, may be explained by these observations. Corn, for instance, the most sensitive plant worked with, is characterized in its seedling stages by a small number of vigorously absorptive growing points.

By means of the more delicate dark-red potassium ferrocyanide test, copper may usually be traced through the vessels of the root systems for considerable distances, showing that it is through these channels that small amounts of the metal finally reach the stems and leaves. Here the maximum amounts of copper are found in the outer and upper portions of the plant, where evaporation is most active, and where the greatest residuum of copper therefore occurs. The potassium xanthate (yellow) and hydrogen sulphide (brown) tests also reveal copper in root structures but are not so satisfactory for this purpose as potassium ferrocyanide. (See frontispiece.)

The above described reactions, which are so conspicuous in water-culture material killed by copper, are very obscure or imperceptible in roots grown in soils containing copper. The

first material, however, is dead and more nearly saturated with copper; while living roots from soil culture, with proteids combined to but a small per cent of their capacity for copper, do not give satisfactory color tests. These reactions, therefore, do not serve for qualitative determinations of toxic effects in field material.

Relations Between Amounts of Copper in Root Systems and Injury to Plants

An effort to establish relations between the amounts of copper in parts per million of dry matter in root systems, and toxic effects as shown in the condition of aerial portions of the plant, was only partially successful; but a sufficient number of observations on samples of sufficient size produced under carefully regulated conditions would probably establish such relations. In the tables shown on the preceding pages there is a fair degree of agreement between the members of each experimental series, the copper found in root systems increasing in most cases with the amount of copper in the soils of each particular series of cultures. In the case of beans and corn grown in cultures containing copper in the form of precipitated carbonate, beans show a somewhat higher resistance to toxic effects and also contain larger amounts of copper in the root systems throughout the series. The conditions under which the samples were grown seem to have, within limits, more effect upon the copper content of root systems than the amounts of copper in the soil, as is indicated in the following tabular statement:

TABLE XXXII

Toxic Concentrations of Copper in Soils and Root Systems

Culture	Points at which toxic effects begin	Cu in root system at point *not* showing toxic effects p.p.m.	Cu in root system at point showing toxic effects p.p.m.
Corn, seven samples from field soils		42 at .07%	
Corn in field plots containing Cu as sulphate	.04%	245 at .025%	296 at .05%
Corn in pot cultures containing Cu as carbonate	.023%	748 at .02%	509 at .025%
Beans in pot cultures containing Cu as carbonate	.035%	950 at .025%	1358 at .05%

In this statement, for instance, field samples of corn roots grown in soil containing 0.07 per cent of copper contained only 42 p.p.m. of copper in dry matter, while a plot sample grown in soil containing .025 per cent of copper contained 245 p.p.m. of copper in dry matter, and corn grown in pot culture containing 0.02 per cent of copper in soil contained 748 p.p.m. of copper in dry matter.

These differences may be due to the coarser root systems of plot and field-grown samples, this condition being associated with relatively small amounts of copper in dry matter. In view of the great labor involved in preparing root samples for analysis and the very variable results obtained from copper determinations made upon such material, there seems to be little hope of establishing satisfactory ratios of copper to dry matter for the purpose of determining that a sample of field material has been injured by copper. It is probable, however, that for comparative purposes, pot cultures of field soils conducted under uniform and carefully regulated conditions, with standard plants of known behavior, may yield figures of comparative value in determining the character, toxic or otherwise, of a soil containing copper. Corn is an excellent summer-growing plant for the purpose, inasmuch as it shows toxic effects easily, grows rapidly, and affords abundant root materials for analytical determinations. For winter cultures, wheat serves well. Both plants are representative of standard crops for the region under discussion.

PATHOLOGICAL EFFECTS

Pathological effects in tops and roots may confirm to a considerable extent, the fact that a plant has been poisoned by copper. The lengthwise yellow striping of corn and wheat leaves due to toxic amounts of copper is not distinctive since the same appearances may result from various other conditions inducing malnutrition, such as those mentioned on a preceding page. Usually, however, careful observation will identify or eliminate these other disturbing factors.

Root systems grown in coppered soils are also conspicuously injured, being stunted in growth, of harsh and crinkly texture

and (in the case of corn) showing characteristic proliferated root tips. The epidermis is thick and rough and the cells in longitudinal tangential section contract from the oblong toward the circular form. Here, again, other factors, such as alkali salts in excess, may lead to similar appearances; and these must be eliminated in a diagnosis of copper injury.

Soil Conditions Relating to Toxic Effects of Copper upon Plants

Certain conditions favor, others oppose the toxic action of copper under field conditions, the general tendency being to modify or do away with toxic effects, where the amounts of copper are not excessive.

Carbon dioxide in the soil, alone and in conjunction with certain salts (NaCl, Na_2SO_4) tends to form solutions of basic copper carbonate. Carbonates (Na_2CO_3,$CaCO_3$) lessen the solubility of basic copper carbonate in carbon dioxide and, therefore, the toxicity of copper compounds in soils containing these carbonates.[22]

Coarse, sandy soils favor toxicity by permitting free movement of solutions and because the withdrawal in them of copper from solution by physical and chemical reactions is minimum.[23]

The character of the compound of copper to which roots are exposed is important. In pot cultures of precipitated carbonate of copper, of sulphide in the form of chalcocite pulverized to go through a 100-mesh sieve, and of silicate in the form of chrysocolla pulverized to 100-mesh, toxic effects appeared with corn as follows:

Pot culture of corn; Cu in form of pptd. carbonate—showing toxic effects at .023% Cu in soil

Pot culture of corn; Cu as chalcocite, 100-mesh—showing toxic effects at .08% Cu in soil

Pot culture of corn; Cu as chrysocolla, 100-mesh—showing toxic effects at .08% Cu in soil

The precipitated carbonate is not only more soluble in carbon dioxide than in chalcocite, but also more easily acted upon

[22] See Bibliography, p. 236, reference 12.

[23] See Bibliography, reference 18.

by the acids of plant roots than chalcocite or, probably, chrysocolla. Under field conditions, copper in tailings is originally mostly in the form of sulphides, chiefly chalcocite, which oxidizes only slowly to sulphate in presence of water and air. Chalcocite, 3.2 grams, shaken up with 600 c.c. of water, and air, for twenty-eight days, yielded only 16 mg. of soluble copper. The soluble sulphate in contact with silicates and carbonates of the soil is converted to insoluble forms. The process is gradual and the amount of soluble copper present at any one time is small.

The tilth of the soil is significant. A pot culture very thoroughly mixed with 0.1 per cent of copper as carbonate resulted in badly poisoned plants containing about four times as much copper in root systems as in a lumpy mixture of soil containing the same amount of copper. The heavy tailings clay, with which copper is chiefly associated in the district studied, tends to remain in lumps and masses, thus minimizing toxic effects of contained copper compounds.

In water cultures toxic effects of copper salts are lessened by salts contained in well-water or in nutrient solutions. This is due, in part, to the presence of other ions, the effect of which is to decrease the ionization of copper salts, with consequent decrease in toxicity. This observation applies to soil-water solutions which contain considerable amounts of alkali salts. It is of interest in this connection to note that certain combinations of salts representing complete mineral nutrients exert maximum antitoxic action to copper salts;[24] and that therefore a fertile soil containing maximum amounts of plant nutrients will tend to minimize toxic effects of copper.

Antagonistic solutions, so called, involving copper, may also account for a decrease in toxicity. By reason of a property of the semipermeable membranes of root systems, ions may be either more readily or less readily allowed to penetrate. When penetration is decreased through the addition of ions of other soluble salts this salt is said to be antagonistic in character. Copper is thus antagonized by sodium and potassium salts, of which the soluble salt content of the soil is chiefly composed.[25]

[24] A. Le Renard, Essai sur la valeur antitoxique de l'aliment complet et incomplet. Abstracted in Science n. s. vol. 28, no. 712, p. 236, 1908.

[25] See Bibliography, p. 237, references 35–44, 52.

Physical attractions, or adsorptive effects, also account for a very considerable lessening of the amount of dissolved copper salts, in contact with soil particles. Jensen, for instance, finds that a dilute copper solution is ten times as toxic in the free condition as when it is mixed with an artificial quartz soil, that is to say, the quartz reduces the toxic effects about nine-tenths. Inasmuch as the reduction in toxicity is a function of the solid surface to which the soluble salts are exposed, the finer the state of division of a soil the more will be the adsorption and the less will be the toxic effects of a stated copper solution.[26]

The age of plant roots markedly affects their susceptibility to copper salts. Young and tender roots, containing large amounts of protoplasm, are much more quickly and easily poisoned than old and comparatively fibrous structures containing a small proportion of protoplasmic materials. This may be due to differences in the thickness of cell walls protecting the cell contents from outside substances; it may be due to a different degree of permeability of the protoplasm of older roots to copper salts; or it may be due to lessened reactivity due to changed chemical character. In any case, this observation indicates a distinctly greater resistance to copper in soils, of older, more fibrous, and possibly intrinsically more resistant root systems. Different species of plants also show varying degrees of resistance to copper salts. In pot cultures, peas are distinctly more resistant to precipitated carbonate of copper than corn. Different plants of the same species also show a certain amount of individuality with reference to absorption of copper.

Stimulation

Not only do the various influences described above lessen the toxic effects of copper upon plants, but it is possible, also, that the amounts of copper may be decreased in the field to the point at which stimulating effects occur. As shown in the discussion of water cultures on preceding pages, extreme dilutions of copper salts in distilled water, for instance, 1 part to 100,-

[26] G. H. Jensen, Botanical Gazette, vol. 43, p. 11, Jan., 1907.

000,000, caused increased growth of root tips growing in these solutions. This observation accords with those of some other experimenters, not only with copper solutions but with solutions of various other metals, and bears a certain analogy to stimulating effects upon animals observed with very small amounts of poisons, such as arsenic and strychnine. Stimulation was also observed in the case of certain pot cultures watered with dilute copper solution in such a way that these solutions were filtered through a thin layer of soil before they reached the plant roots. Under these conditions a portion of the root systems must come in contact with extremely dilute copper solutions residual from the reactions of copper salts with the soil. As in the case of water cultures, these extremely dilute solutions must have exerted the stimulating effects which were apparent in several cultures made in this manner.

In the case of pot cultures also, in which stated amounts of copper were uniformly mixed throughout the soil, apparent stimulation of growth was occasionally observed; for instance, with 0.01 per cent of copper in the form of precipitated carbonate in a culture of corn.

A satisfactory explanation of stimulation effects is not available. It is to be supposed that stimulation in a soil culture in which copper sulphate is used may be explained by the action of the SO_4 ion upon the soil in releasing plant food for the use of the plant. However, such stimulation is seen in water cultures where this does not occur. Lipman[27] has observed that under certain conditions the nitrifying flora of soils is stimulated by salts of copper, zinc, iron and lead. Such stimulation, through increased elaboration of nitrates, may account for the behavior of cultures showing increased growth. Stimulation effects, therefore, which undoubtedly occur both in water and in soil cultures, are perhaps due to more than one different cause—to chemical and bacterial agencies in soils, and to a pathological disturbance in water cultures.[28]

Taking into account the very minute amounts of copper salts with which stimulated growth is associated, and the very gradual

[27] Lipman, C. B., and Burgess, P. S., Univ. Calif. Publ. Agr. Sci., vol. 1, no. 6, pp. 127–139, 1914.

[28] See Bibliography, pp. 236–237, references 2, 4, 27, 33, 53, 45.

addition of copper to new ground that may occur through irrigating waters, it is not impossible that in favorable situations an actual increase in vegetable growth in the field due to copper may take place; but it is not possible in the field to prove this supposition because of many other factors, the effects of which prevent trustworthy observation.

Field Observations

In view of the many factors influencing results in the field, some leading towards toxic copper effects, some opposing toxic effects, and still others pointing to the possibility of stimulated growth, it is of interest, finally, to refer to field conditions as they have existed in irrigated lands under the Clifton-Morenci mines for the twelve years during which the district has been under observation. At the beginning of this period, in 1904, considerable accumulations of copper-bearing tailings were evident, more particularly at the heads of alfalfa fields, where they sometimes attained a thickness of as much as ten inches or more. These blankets usually thinned out and disappeared between 100 and 200 feet from the head ditches, leaving crops in lower portions unaffected. Deposits of river sediments were observed in other irrigated districts not affected by mining detritus. The growth of alfalfa was more depreciated by the denser and thicker tailings blankets; and yellow foliage of young grain and young corn was considerably in evidence in tailings, but not as an effect of ordinary sediments. In 1908, the tailings were impounded, and some of the best farmers began the practice of cultivating alfalfa to break up the old accumulations, incorporate them with the soil, and secure better penetration of water and air to the roots of the crop. Following this procedure the stunted growth at the heads of alfalfa lands has considerably but not yet entirely recovered. Patches of yellow young barley, wheat, and oats are still to be observed on old tailings deposits; but as the plants become older they become normal in appearance, and yield apparently normal crops. These observations, which may be repeated many times in the course of a day's reconnaissance in the district, from May to September for alfalfa, and February

to May for grain, may be explained by the following considerations: The wedge-shaped deposit of tailings indicated in the diagram (fig. 15) at first so obstructed access of water and air to alfalfa root-systems that only stunted development was possible either of roots or tops. With an annual cultivation of this blanket and the incorporation of river sediments and better penetration of irrigating waters, deleterious effects tend to disappear and the crop again approaches normal.

Similar land when plowed for grain contains most of the copper associated with old tailings at the surface of the soil. Young grain, therefore, with shallow and susceptible root sys-

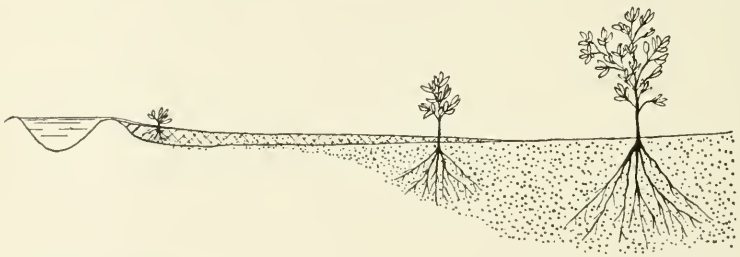

Fig. 15.—Diagram showing behavior of root systems under influence of tailings blanket.

tems, at first, if ever, shows effects of copper in the soil, recovering as root systems penetrate to greater depths where they encounter uncontaminated soil.

EFFECTS OF RIVER SEDIMENTS

With reference to the further trend of copper effects upon vegetation in the district, assuming the permanent exclusion of solid tailings but a constant addition of about one part of copper to one million of irrigating water used, it is of interest to take into account the diluting effect of river sediments upon copper compounds in the district.

In four acre-feet of Gila River water, these sediments will amount to about eighty tons per acre a year,[29] of which amount the ten pounds of copper contributed in irrigating waters is only 0.006 per cent.

[29] Forbes, R. H., Ariz. Agr. Exp. Sta. Bull. 53, p. 61.

Irrigating sediments alone, therefore, considered in their general relation to amounts of copper which cannot be prevented from reaching irrigated fields, are sufficient in quantity to reduce ultimately the amounts of copper observed below 0.01 per cent in the soils of this district. Since 0.01 per cent is a safe minimum, river sediments, alone, incorporated with the soil are probably sufficient to ameliorate gradually existing accumulations of copper salts and to take care of further contributions in soluble form which cannot at present be avoided.

Effect of Cultivation upon Alfalfa

Finally, it is of interest to observe the improvement in a field of alfalfa, in the district studied, between the years 1905 and 1916.

June 23, 1905, the writer carefully measured, cut and weighed a representative plot of alfalfa in William Gillespie's field near Solomonville, Arizona. This field was suffering from an accumulation of tailings, the depreciation in yield at the upper ends of alfalfa lands being conspicuously evident. Following the exclusion of tailings from the irrigating supply in 1908, and with a cultivation each winter with a disk or a spring-tooth harrow, the condition of the field gradually improved until, June 13, 1916, the writer returned and again measured, cut, and weighed the identical plot of alfalfa that had shown bad effects eleven years before. Following are the data, with diagrams, relating to these two cuttings of alfalfa, which are representative for the district within which tailings were deposited.

1. *Alfalfa seriously affected by tailings, June 23, 1905.*

Three lands in William Gillespie's field east of house, near Solomonville, under Montezuma Ditch, out of Gila River. A good stand of alfalfa five years old. Heavy adobe soil; field never disked.

The three lands observed were, over all, 95 feet wide, and divided into plots 100 feet long from top to bottom of field. Ten feet next the ditch was discarded because of banks and bare spots, and the extreme lower portion of the field because of roadways. A portion of plots 6 and 7 was discarded on account of Johnson grass.

Observations were made June 23, 1905, on the second cutting, just beginning to bloom, the field having been irrigated twice since the last cutting. After stirring and raking, the yield of dry hay was weighed June 24. Weather very hot and dry. Following are the data relating to this series:

Plot	Dimensions in feet	Height of alfalfa, inches	Yield of plot, pounds	Tons per acre	Depth of tailings on plot, inches	Condition of surface soil at time of cutting
1	95×100	19	240	.69*	1½–3½	Dust-dry and somewhat cracked
2	95×100	20	340	.87*	1 –2	Dry and badly cracked
3	95×100	23–25	570	1.31	¾–1¼	Dry, cracked at upper end
4	95×100	24	595	1.36	½–1	Moist, not cracked
5	95×100	23	550	1.26	¾–1	Moist, not cracked
6	60×100	28	400	1.41*	½–1	Moist, not cracked
7	60×100	27	430	1.48*	⅓– ½	Moist, not cracked

* Corrected for thin stand and trash.

2. *Alfalfa slightly affected by tailings, June 13, 1916.*

The same three lands, continuously in alfalfa since 1905. A perfect stand, thin spots reseeded by means of a seed crop in 1915. The field had been spring-tooth harrowed each winter for about ten years, especially at heads of lands, to break up the tailings blanket and secure better penetration of irrigating water.

As in 1905, ten feet next the ditch was discarded, also the extreme lower portion of the field. Johnson grass had nearly entirely disappeared.

Observations were made June 13, 1916, on the second cutting, just beginning to bloom, the field having been irrigated twice since the last cutting. After raking and piling, the dry hay was hauled and weighed June 17. The weather was moderately hot and dry; and conditions generally the same as those under which the crop was cut in 1905. Following are the data for the second series of observations:

Plot	Dimensions in feet	Height of alfalfa, inches	Yield of plot, pounds	Tons per acre	Appearance of tailings	Condition of soil at time of cutting
1	95×100	36–21	875	2.00	Distinct	Surface dusty, drier soil
2	95×100	22–34	857	1.96	Distinct	Surface dusty, drier soil
3	95×100	34–36	972	2.22	Slight	Moist throughout
4	95×100	30–36	910	2.08	None	Moist throughout
5	95×100	31–33	900	2.05	None	Moist throughout
6	95×100	28–36	860	1.96	None	Moist throughout
7	95×100	34–37	870	1.98	None	Moist throughout
8	95×100	33–36	910	2.08	None	Moist throughout

Comparing these two statements, and illustrating them by means of the following diagram (fig. 16), it is evident that the depreciation in yield observed in the upper plots in 1905 has disappeared in 1916, the yields on the last date being practically uniform from top to bottom of the field. Effects of tailings are still plainly visible in plots 1 and 2 in spots and patches of short alfalfa, compensated for, however, by areas of stimulated growth apparently due to seepage from the adjacent ditch. The yield of the field as a whole is also much improved due to cultivation and reseeding of the field.

In brief it may now be stated that, following the exclusion of tailings from the irrigating waters of this locality, it has been found possible, in this carefully observed case, to overcome the deleterious effects of tailings deposits upon alfalfa, slowly but almost entirely, in about ten years.

Thus, co-operation between miners, in restraining tailings from irrigating streams, and those farmers who cultivate their alfalfa intelligently, effectually disposes of the most serious problem that has arisen in connection with copper-mining detritus.

The chemical composition of tailings, in fact, would indicate that, as in the case of humid region subsoils, when they are enriched by the addition of organic matter and nitrogen, and filled with bacterial life, they may make very good soil. Following is a statement of the composition of four representative samples of ores and tailings, with reference to potash and phosphoric acid:

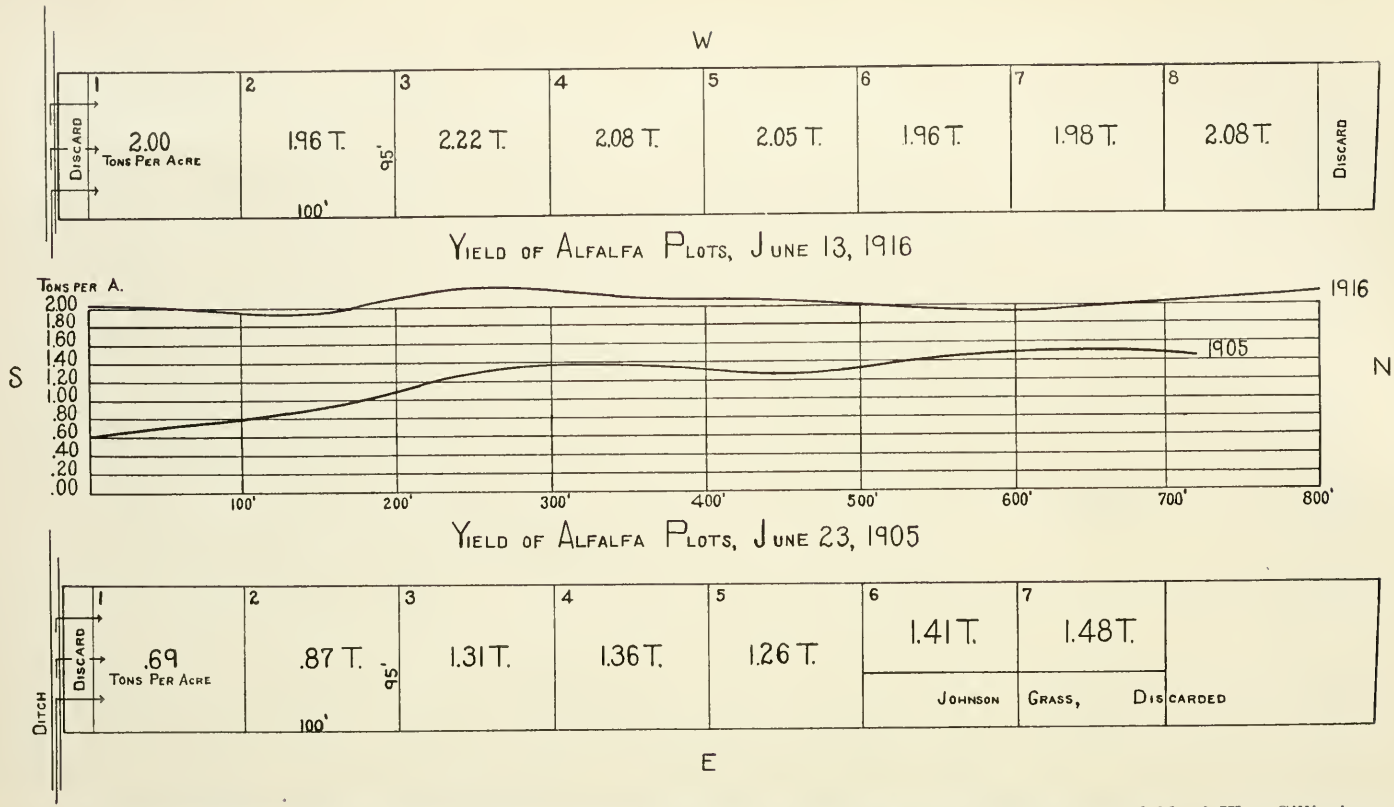

Fig. 16.—Diagram showing yields of alfalfa from head to foot of a land damaged by tailings in the field of Wm. Gillispie, east of house, June 23, 1905; and the same land June 13, 1916, tailings having been kept out of the water since 1908, with the field disk-harrowed annually.

Sample No.		Potash K_2O	Phosphoric acid P_2O_5	*Nitrogen N
3491	Sulphide ore	.64%	.11%	Doubtful
3492	Oxidized ore	.44	.11	
3438	Sulphide tailings	.79	.29	traces
3439	Oxidized tailings	.67	.12	

These ores and the tailings derived from them are rich in potash, and contain unexpectedly large amounts of phosphoric acid; but nitrogen is almost nil.

SUMMARY

1. Copper is shown, as a direct effect of the Clifton-Morenci mining operations in Arizona, to be distributed throughout water-supplies, soils, the vegetable and the animal life of an underlying irrigated district.

2. Smaller amounts of copper are found elsewhere in the State where the drainage basin includes mining operations or ore-bearing areas.

3. Individual plants grown in water cultures or in soil containing copper show a comparatively small, and probably not injurious, accumulation of copper in the aerial portions of the plants; but the root systems, carefully cleansed of externally adhering copper, contain relatively great amounts.

4. Copper in root systems, as shown by the biuret test, is largely in combination with plant proteids, especially at the growing points of root systems and near vicinity. The place and nature of the reaction accounts for the extreme toxicity of copper salts to plants. The varying sensitiveness of plants to copper salts may possibly be explained in part by the number and disposition of exposed growing points.

5. Conditions favoring toxicity of copper compounds are the presence of carbon dioxide and certain soluble salts which assist in forming copper solutions that come into contact with plant roots; coarse, sandy soils favoring free access of copper solutions to plant roots and minimizing the withdrawal of copper from solution by adsorption; and the presence of copper in the form of the more soluble precipitated carbonate.

6. Conditions opposing toxicity of copper compounds are the presence of copper in the form of chrysocolla and chalcocite: adsorption through contact with finely divided soil particles; reactions with carbonates, silicates, and organic matter tending to precipitate copper from its solutions; the presence of certain soluble salts in the soil that overcome toxic action; and increased resistance of old plant roots.

7. The stimulation by copper of vegetative growth in pot and water cultures has been observed. Stimulated growth of crops under field conditions is a possibility.

8. Pot cultures may be used for comparative determinations of toxic effects upon plants of copper in soils, if conducted under rigidly uniform conditions. The copper content and the physiological response to copper of such material will be much greater than for similar cultures grown under plot or field conditions.

9. Copper injury in field soils containing doubtfully toxic amounts of copper may be diagnosed by a combination of symptoms. Facts which indicate such injury in a soil containing 0.1 per cent of copper (more or less) are: yellow tops (for winter grains) in absence of other conditions that cause yellow tops; crinkly root systems (in absence of excessive amounts of alkali salts); and a high copper content in dry matter of root systems. Combined evidence of this character, which may be observed in the district studied, indicates toxic copper effects.

10. Field observations before and following the exclusion of tailings from the irrigating water-supply indicate that conditions in the district studied are gradually improving, due to the cultivation of alfalfa and to the incorporation of river sediments with accumulations of tailings. Noticeable toxic effects in the field exist only where the roots of young, growing crops are exposed to surface soils containing maximum amounts of copper. The general tendency in the district is probably toward decreasing rather than increasing percentages of copper in irrigated soils.

11. Methods of analysis have been developed for the purpose of determining reliably small amounts of copper in vegetative material, particularly in root systems of plants grown in soils containing copper.

Part III.—APPENDIX

METHODS OF ANALYSIS

With the Collaboration of E. E. Free and Dr. W. H. Ross

Freedom of samples, especially vegetation, from contamination with adhering copper; and accurate methods for determining minute amounts of copper in sediments, soils, waters and vegetation, are vital to the integrity of the work recorded in this publication.

Unusual care was taken to perfect methods for preparation of samples, especially roots grown in media containing copper; and refined manipulation in the determination of copper reduced the limit of error to approximately .00001 gram, or .01 milligram.

Reagents and Apparatus

Distilled water of three derivations was used: (1) University of Arizona well water very slowly distilled through a block-tin worm; (2) the same, redistilled from glass; and (3) University of Arizona well water distilled from glass.

Nitric and sulphuric acids from Baker & Adamson were used.

Ammonia and H_2S employed were passed through two wash bottles.

Blank determinations from time to time with reagents employed gave no trace of copper, thus insuring results obtained by means of them.

Copper was determined by electrolysis, in minute amounts according to the manipulation of E. E. Free.[1]

The balance used was a No. 2112 Eimer and Amend short-beam assay balance, "distinctly sensitive to 1/200 milligram."

Manipulation

Ores and tailings.—1–2 gms. were digested with a mixture of 8 c.c. HNO_3 and 5 c.c. HCl on a hot plate, then 4 c.c. H_2SO_4 added and evaporated to H_2SO_4 fumes (method used in Old Dominion laboratory at Globe, and Copper Queen at Bisbee). Took up with water, filtered, neutralized with ammonia, then added 2 c.c. H_2SO_4 and a few drops of HNO_3 and electrolyzed.

Soils.—Soils were examined by two methods:

(*a*) 100 gms. soil was treated with a mixture of 80 c.c. HNO_3 and 20 c.c. H_2SO_4 and digested in a porcelain dish on a hot plate to sulphuric fumes; digested with 200 c.c. water, filtered, washed up to about 500 c.c., evaporated to 200 c.c. precipitated iron with ammonia, filtered, washed with about 500 c.c. water, alkaline filtrate reduced by evaporation, acidified faintly with HCl and H_2S passed for half an hour. The faint black precipitate was

[1] Electrolytic determination of minute quantities of copper, 12th Gen. meeting Am. Electrochem. Soc., October 17–19, 1907.

allowed to settle several hours, then filtered, and the precipitate, including filter, digested with 5–10 c.c. HNO_3 and water until copper was dissolved, solution filtered, a few drops of H_2SO_4 added, evaporated to fumes, and copper determined by electrolysis with addition of 5–25 drops of HNO_3.

(*b*) 200 gms. soil was digested as above with HNO_3 and H_2SO_4, evaporated to fumes of H_2SO_4, digested with water, filtered and washed up to 500 c.c., made alkaline with ammonia and made up to 1000 c.c. After settling, 500 c.c. or 100 gms. aliquot, was filtered off and copper determined as in (*a*).

Waters.—Waters were evaporated to dryness, the residue digested with sulphuric acid and water, filtered hot, excess of H_2SO_4 evaporated, filtered into platinum dish, a few drops of HNO_3 added, and electrolyzed.

Vegetation.—Air-dried samples were burned in a small sheet-iron stove, the iron of which was found to contain *no trace* of copper. Two samples of mistletoe, difficult to burn, were reduced in a *new* muffle in gasoline assay furnace. The charred and partly burned material was moistened with water, and concentrated HNO_3 added (100 to 200 c.c.) until effervescence ceased, digested until in plastic condition, diluted with hot water and filtered. Evaporated bulky filtrate to dryness, took up with water and HNO_3, filtered (getting rid of much organic matter), added about 20 c.c. H_2SO_4, evaporated to H_2SO_4 fumes, driving off all but about 5 c.c. H_2SO_4, added water, filtered off insolubles, made up filtrate to about 500 c.c., passed H_2S, and proceeded as usual for copper.

The completeness of the extraction of copper from vegetation by the above method was verified as follows: The extracted, charred residue from 2 lb. 8 oz. of dry corn leaves and blooms in which 1.32 parts Cu per million was found (Sample 3529) was removed from filter paper after washing, moistened with H_2SO_4 and additionally burned in a porcelain dish, being finally reduced, after again moistening with H_2SO_4, in a platinum dish in the muffle. The resulting pink ash was then fused with three parts of dry Na_2CO_3 (Kahlbaum) and poured on clean porcelain. The fusion was soaked in water with addition of H_2SO_4, evaporated nearly to dryness, filtered from insoluble portion (lime, salts, etc.), again evaporated and filtered, and a third time the same, finally driving off excess of H_2SO_4 and electrolyzing as usual. A black precipitate of carbon but *no Cu* was obtained, the same being true of a blank determination on the Na_2CO_3 used.

Roots of plants grown in water cultures or in soils must be most thoroughly cleansed of externally adhering copper, since this will introduce excessive errors where the content of copper is small. Three methods of preparing roots for copper determination were employed:

1. Roots grown in water cultures containing copper were dipped for about ten seconds in 4 per cent HCl, immediately

washed in copper-free water and dried. Careful observation indicated that adhering copper salts deposited from water solution were completely removed by this treatment. It is probable that the acid penetrates plant tissues somewhat in the time employed and removes some copper. The results are, therefore, probably severely conservative.

2. Roots grown in soil cultures containing copper cannot be safely cleansed with HCl, which does not readily dissolve silicates and sulphides of copper, and which cannot be allowed to remain in contact with plant roots for more than a few seconds.

Carbon dioxide in water was finally selected as a mild, slow but finally effective solvent for the purpose. Samples of roots were first very thoroughly washed in copper-free well-water, then placed in five-liter jars with ground glass covers, a stream of washed CO_2 passed, the jars shaken and treatment with CO_2 repeated until the water was saturated, then allowed to stand with occasional shaking for twenty-four hours. The solution was then siphoned or filtered off and the treatment repeated until, on evaporating the bulky filtrates, no more copper was found. To prevent putrefaction during long-continued washings, a pinch of thymol was added to each washing. From nine to thirty-one washings were found necessary to cleanse plant roots thoroughly, the process being laborious and time-consuming. When the sample yielded no more copper to wash waters it was dried, burned and copper determined according to the method for small amounts in plant ashes.

Following is a record of washings for examples of roots cleaned by this process:

(1) Corn roots grown in a pot culture of soil containing 0.01 per cent of copper as basic carbonate.

	H_2S test		Quantitative by electrolysis
First wash	distinct		
Fifth wash	distinct		
Ninth wash	doubtful	1 liter of filtrate	no Cu

(2) Corn roots grown in a pot culture of soil containing 0.05 per cent copper as Cu_2S.

		Quantitative by electrolysis
Tenth wash	2 litres of filtrate	.00006 gm. Cu

(3) Barley roots from field soil containing tailings.

		Quantitative by electrolysis
First wash	2.433 litres of filtrate	.00035 gm. Cu
Second wash	2.531	.00012
Fifth wash	2.22	.00009
Sixth wash	2.41	.00004
Seventh wash	2.00	.00002
Eleventh wash	2.00	.00000

(4) Coarse roots of field corn grown in soil containing tailings.

	H_2S test	Quantitative by electrolysis
Twenty-fifth wash	distinct	
Twenty-ninth wash		.00005 gm. Cu
Thirty-first wash		.00000

Samples vary as to number of washings required to remove the last trace of copper, but the definiteness with which, finally, copper usually ceases to be extracted by CO_2 water indicates completeness of the operation. This is further emphasized by the comparatively large amounts of copper which are then found in root systems thus cleansed.

3. A third method of preparing roots for copper determination, involving less labor than by washing in CO_2 water, is as follows: Cleanse roots thoroughly in clean water with a camel-hair brush, dry, burn and weigh the ash, then estimate total copper. Determine copper in soil shaken from sample, assume ash as all soil and deduct copper in this amount of soil from total copper found in ash. Results by this method are low, but not seriously in error if sample is thoroughly washed.

Example	Dry matter	Ash	Gms. Cu	Pts. Cu per million
Sample 2*a* grown in soil containing 0.05% copper	.3561 gm.	10.84%	.000115	322
Ash in sample	.0386			
Copper in ash assumed as soil			.000019	
Net copper assumed			.000096	270

The correction introduced reduces parts per million of copper from 322 to 270, which latter figure is conservative in character.

Of the three methods above described, No. 2 is undoubtedly most exact, but is extremely laborious and time-consuming.

THE DETERMINATION OF COPPER IN SMALL AMOUNTS OF PLANT ASHES

The ash is placed in a platinum dish without previous pulverization and moistened with concentrated sulphuric acid in sufficient quantity to bring all parts of the ash in intimate contact with the acid. The material is then thoroughly stirred and heated on a sand bath until fumes of SO_3 begin to come off, then allowed to cool and a sufficient quantity of hydrofluoric acid added to bring the acid in contact with the whole mass, then allowed to stand for at least half an hour and again heated until

SO_3 fumes come off. The material is now washed into a casserole, moistened with sulphuric and nitric acids and digested at a low heat for at least one hour. The heat is then increased until SO_3 fumes are again driven off. The mass is moistened with three to four times its bulk of distilled water and digested at a gentle heat from one to two hours, filtered hot and then the filtrate and washings evaporated almost to dryness, thus driving off the excess of sulphuric acid. The resulting residue is taken up with hot water and again filtered to separate the solution from precipitated calcium sulphate. This evaporation and filtration may have to be repeated one, two or three times in order to get the solution sufficiently free from calcium sulphate. The final filtrate, which contains the copper, is then diluted to about 150 to 200 c.c. in a tall beaker, a small quantity of hydrochloric acid is added and hydrogen sulphide passed until the solution is thoroughly saturated. During the hydrogen sulphide precipitation there should be no nitric acid or nitrates present in the solution. A large quantity of organic matter is also disadvantageous and may be avoided by evaporating the solution several times to dryness with nitric and sulphuric acids, finishing finally with an evaporation with sulphuric acid alone in order to drive off all traces of nitric acid.

The precipitate from the treatment with hydrogen sulphide is filtered off, washed with water saturated with hydrogen sulphide and digested with a small quantity (2 to 5 c.c.) of nitric acid in a casserole. The digestion should be begun cold and the heat gradually increased. If the digestion is begun at a high temperature the sulphur formed by the decomposition of the copper sulphide will form a film of molten sulphur around the granules of copper sulphide, and this tends to prevent their solution in nitric acid. The precipitate after digestion in nitric acid should be a clear green or else a yellow. If there is any trace of dark color, brown or black, it means that either organic matter has been precipitated with the copper sulphide precipitate, which is extremely unlikely, or else that the above-mentioned sulphur film has formed around some of the particles of copper sulphide preventing their solution in the nitric acid. If the latter be the case, the determination may still be saved by placing the precipitate in a platinum dish and heating over a gentle flame until the sulphur is volatilized. The residue of copper sulphide or of copper oxide may then be digested in nitric acid. The digestions in nitric acid should not be carried to a heat high enough to decompose the copper nitrate formed by the solution of copper sulphide.

After digestion in nitric acid and the evaporation of any large excess of nitric acid, the residue is taken up in hot water, acidified to contain 2–4 per cent nitric acid and filtered into a large platinum dish, ¼ to ½ c.c. of sulphuric acid is added, and the solution electrolyzed with a voltage of from 2 to 2½

volts and a current not greater than one ampere. The voltage may be higher than 2½ volts if necessary but should not be high enough to raise the current beyond the limit given. The electrolysis should be continued at least three hours and preferably nine to twelve hours. The dish is, of course, the cathode. When the electrolysis is complete the electrolyte is washed out of the dish by means of the sucking-bottle and the dish is thoroughly washed with distilled water. In case the deposit of copper on the dish is spongy and loosely adherent it is not safe to wash out the electrolyte. In this case the copper should be redissolved and the electrolysis repeated, using a little more sulphuric acid. If the copper still refuses to come down in adherent form the addition of 2 to 5 c.c. of a one per cent solution of gelatine will often assist the precipitation. In case of a stubborn refusal of the copper to give an adherent deposit it is necessary to dissolve it, evaporate to dryness with sulphuric acid, and reprecipitate with hydrogen sulphide, continuing the process from this point as before.

If the copper refuses to come down at all the trouble is probably an excess of acid in the solution. This may be corrected by the addition of a few drops of ammonia. The concentration of acid in the solution must lie between one and five per cent. At least a small part of this should be sulphuric acid as nitric acid will be destroyed in the course of the electrolysis if it alone is present, and the solution may become alkaline (from NH_4OH), which will prevent proper precipitation. Chlorides and organic salts, such as acetates and tartrates, should be carefully avoided.

The resulting deposit of copper will probably contain traces of carbon and possibly of platinum. In order to eliminate these and at the same time precipitate copper upon an electrode more suitable for accurate weighing, a second electrolysis is made, using this time the dish as anode and using as cathode a small spiral of platinum wire suspended from a hook of silver (or platinum) wire which in turn is connected to the battery. The electrolysis should also be conducted in nitric and sulphuric acid solution and what is said above as to obtaining satisfactory deposits applies with equal force here. In this case, however, owing to the small surface area of the cathode, it is necessary to work with very much smaller currents than were used in the first electrolysis. The maximum current to be used must be so adjusted by trial as to give bright and adherent deposits. 1–100th ampere and 1.8 volts is a good current for the purpose. It is well to use as the source of current for this electrolysis four Edison-Lalande cells and to have in the circuit a resistance of from 30 to 80 ohms. This gives an electromotive force at the dish of about 1.8 volts. Two determinations may be run in parallel. In this case it is not permissible to use a gelatine solution in order to secure satisfactory deposits, as the copper will be slightly contaminated with gelatine and the obtained weight will be too high.

The electrolysis should be run at least nine hours. When completed, the electrolyte should be washed out as before without breaking the current, the electrode lifted from the solution, disengaged from the supporting hook, and washed and dried by dipping successively in water, alcohol and ether and placing in a desiccator over sulphuric acid. After having remained in the desiccator for an hour the electrode is ready for weighing. Weighings should be made on an assay (button) balance adjusted to maximum sensibility. After weighing, the copper is removed from the electrode by dipping in concentrated nitric acid, and the electrode cleaned and dried by dipping successively in distilled water, alcohol and ether and placing in a desiccator. It is again weighed as before and the difference of the two weights gives the copper obtained.

The electrolyte (from each electrolysis) which has been washed out of the dish by means of the suction flask, is evaporated to dryness taken up with water, acidified with nitric acid and tested for copper by electrolyzing, using the point of platinum wire as cathode. In this way any possible loss of copper by incomplete precipitation in either of the electrolyses is prevented. If any copper is found in this check test it should be dissolved from the platinum wire, added to the solution obtained by dissolving the copper from the small electrode, and the electrolysis repeated in order to get the true weight.

In case a quantity of copper too small to be weighed is obtained its identity as copper may be most easily established by electrolyzing it onto the point of a platinum wire as described above. In these electrolyses with the platinum wire as cathode the current must, of course, be kept low in order to obtain satisfactory deposits. If this precaution is observed the deposit on the platinum wire will be of a brilliant red color and easily distinguishable as copper. If the deposit is brownish or blackish its identity as copper may be established by the green flash when the point of the wire is held in the colorless flame of the Bunsen burner, particularly if the wire has been first dipped in hydrochloric acid. Nitric acid must not be used, as nitric acid itself will give a green flash in the Bunsen burner flame.

The reagents used in the above process should all be tested as to freedom from copper. The water used should be doubly distilled and, at least the second time, from glass. All utensils should be cleaned by boiling in nitric acid. Care must also be taken to conduct the operations in rooms free from dust which might possibly contain copper.

BIBLIOGRAPHY

[1] Aderhold, R., Zur Frage der Wirkung des Kupfers auf die Pflanze. Ber. deut. bot. Ges., vol. 24, p. 112, 1898.

[2] Bain, S. M., The action of copper on leaves, Tenn. Agr. Exp. Sta., vol. 15, Bull. 2, 1902.

[3] Barker, B. T. P., and Gimingham, C. T., The action of Bordeaux mixture on plants, Ann. Appl. Biol., vol. 1, no. 1, pp. 9–21, May, 1914.

[4] Brenchley, W. E., Influence of copper sulphate and manganese sulphate upon the growth of barley, Ann. Bot., vol. 24, no. 95, p. 571, 1910.

[5] Brenchley, W. E., Inorganic plant poisons and stimulants, pp. 15–35. (1914.)

[6] Burrill, T. J., Effect of copper on bitter-rot spores, Illinois Exp. Sta. Bull. 118, p. 569, Sept., 1907.

[7] Clark, H. W., and Gage, S. DeM., On the bactericidal action of copper, Jour. Infect. Dis., Supplement no. 2, Feb., 1906.

[8] Collier, Peter, Influence of copper compounds in soils upon vegetation, N. Y. Agr. Exp. Sta. Bull. 41, pp. 35–43, April, 1892.

[9] Coupin, H., Sur la toxicité des sels de cuivre à l'egard des vegetaux superieurs, Compt. rend., Acad. Sci., vol. XCCVII, p. 400, 1898.

[10] Devaux, H., Fixation of metals by cell membrane (Tr.), *ibid.*, vol. 138, p. 58, 1901.

[11] Ewert, Dr., A chemical-physiological method for determining small amounts of copper in extreme dilution (Tr.), Zeitsch. f. Pflanzenkrankh., vol. 14, p. 135, 1904.

[12] Free, E. E., The solubility of precipitated basic copper carbonate in solutions of carbon dioxide, Jour. Am. Chem. Soc., vol. 30, no. 9, p. 1366, Sept., 1908.

[13] Free, E. E., The electrolytic determination of minute quantities of copper, Proc. Am. Electrochem. Soc., Oct. 17–19, 1907.

[14] Freytag, Dr., Die schädliche Bestandtheile des Huttenrauchs der Kupfer- Blei- und Zink-Hutten und ihre Beseitigung, Landw. Jahrb., vol. 11. 1882.

[15] Haselhoff, E., Concerning the injurious effect of water containing copper sulphate and copper nitrate upon soil and plants (Tr.), Landw. Jährb., vol. 21, p. 263, 1892.

[16] Hattori, H., Studies upon the effect of copper sulphate upon certain plants, Jour. Coll. Sci., Univ. Tokio, vol. 15, pt. III, 1901.

[17] Haywood, J. K., Injury to vegetation and animal life by smelter wastes, U. S. D. A., Bur. Chem. Bull. 113 (revised), July, 1910.

[18] Jensen, G. H., Toxic limits and stimulation effects of some salts and poisons in wheat, Bot. Gaz., vol. 43, p. 11, Jan., 1907.

[19] Kirchner, O., Über die Beeinflussung der Assimilationstätigkeit von Kartoffelpflanzen durch Bespritzung mit Kupfervitriol Kalkbrühe, Zeitschr. f. Pflanzenkrankh., vol. 18, Heft 2, p. 65, 1908.

[20] Kraemer, Henry, The copper treatment of water, Am. Jour. Pharm., vol. 76, no. 12, p. 574, Dec., 1904.

[21] Kraemer, Henry, The use of metallic copper for the purification of drinking water, *ibid.*, vol. 78, no. 3, p. 140, March, 1906.

[22] Kraemer, Henry, The use of copper in destroying typhoid organisms, and the effects of copper on man, *ibid.*, vol. 77, no. 6, p. 265, June, 1905.

[23] Lehmann, H. B., Der Kupfergehalt von Pflanzen und Thieren in kupferreichen Gegenden, Archiv. für Hygiene, vol. 27, p. 1, 1896.

[24] Lipman, C. B., and Wilson, F. H., Toxic inorganic salts and acids as affecting plant growth, Bot. Gaz., vol. 55, no. 6, p. 409, 1913.

[25] Lipman, C. B., and Burgess, P. S., The effect of copper, zinc, iron and lead salts on ammonification and nitrification in soils, Univ. Calif. Publ. Agr. Sci., vol. 1, no. 6, pp. 127–139, March, 1914.

[27] Livingston, B. E., Chemical stimulation of a green alga, Contr. N. Y. Bot. Garden, no. 63, 1905.

[28] Long, J. H., The physiological significance of some substances used in the preservation of food, Science, n.s., vol. 37, no. 950, p. 401, March, 1913.

[29] Luckey, Use of copper sulphate in fertilizer, U. S. P. 838036, 1906.

[30] Miani, D., Über die Einwirkung von Kupfer auf des Wachsthum lebender Pflanzenzellen, Ber. deutsch Bot. Ges., vol. 19, p. 461, 1901.

[31] Michigan Acad. Sci., The toxic action of copper sulphate upon certain algae in the presence of foreign substances, Seventh Report, p. 48, 1905.

[32] Moore, Geo. T., and Kellerman, Karl F., A method of destroying or preventing the growth of algae and certain pathogenic bacteria in water supplies, U. S. D. A., Bur. Pl. Ind., Bull. 64, May, 1904.

[33] Ono, H., Über die Wachsthumsbeschleunigung einiger Algen und Pilze durch chemische Reize, Jour. Coll. Sci. Univ. Tokio, vol. 13, p. 141, 1900.

[34] Otto, R., Investigations concerning the behavior of plant roots towards solutions of copper salts (Tr.), Zeitschr. f. Pflanzenkrankh., Bd. 3, 1893.

[35] Osterhout, W. J. V., The decrease of permeability due to certain bivalent kations, Bot. Gaz., vol. 59, no. 4, p. 317, April, 1915.

[36] Osterhout, W. J. V., Extreme alterations of permeability without injury, *ibid.*, vol. 59, no. 3, p. 242.

[37] Osterhout, W. J. V., Protoplasmic contractions resembling plasmolysis which are caused by pure distilled water, *ibid.*, vol. 55, no. 6, p. 446, June, 1913.

[38] Osterhout, W. J. V., Quantitative researches on the permeability of plant cells, Plant World, vol. 16, p. 129, May, 1913.

[39] Osterhout, W. J. V., Permeability of protoplasm to ions and the theory of antagonism.

[40] Osterhout, W. J. V., On the nature of antagonism, Science, n.s., vol. 42, no. 1050, p. 255, February, 1915.

[41] Osterhout, W. J. V., Extreme toxicity of sodium chloride and its prevention by other salts, Jour. Biol. Chem., p. 363, March, 1906.

[42] Osterhout, W. J. V., Plants which require sodium, Bot. Gaz., vol. 54, no. 6, p. 532, December, 1912.

[43] Osterhout, W. J. V., Organization of the cell with respect to permeability, Science, n.s., vol. 38, no. 977, p. 408, September, 1913.

[44] Osterhout, W. J. V., Vitality and injury as quantitative conceptions, *ibid.*, vol. 40, no. 1031, p. 488, October, 1914.

[45] Porchet, F., and Chouard, E., De l'action des sels de cuivre sur les vegetaux, Bull. de la Muriethienne, vol. 33, 1905.

[46] Phillips, F. C., Absorption of metallic oxides by plants, Chem. News, vol. 46, p. 224, March, 1882.

[47] Reed, H. S., Abstract of Essai sur le valeur antitoxique de l'aliment complet et incomplet, by A. Le Renard, Science, n.s., vol. 28, no. 712, August, 1908.

[48] Ritthausen, H., Verbindungen der Proteinstoffe mit Kupferoxyd, Jour. f. prakt. Chem., Bd. 5, p. 215, 1872.

[49] Ritthausen, H., Verbindungen der Eiweisskörper mit Kupferoxyd, *ibid.*, Bd. 7, p. 361, 1873.

[50] Rumm, Ueber die Wirkung der Kupferpräparate, etc., Ber. deut. Bot. Ges., vol. 11, p. 79, 1893.

[51] Schander, R., Ueber die physiologische Wirkung der Kupfervitriol Kalkbrühe, Landw. Jahrb., vol. 33, p. 517, 1904.

[52] Stiles and Jorgensen, I., Studies in permeability, Ann. Bot., vol. 29, no. 115, p. 349, July, 1915.

[53] Stockberger, W. W., Effect of some toxic solutions on mitosis, Bot. Gaz., vol. 49, p. 416, June, 1910.

[54] Sullivan, E. C., Precipitation of natural silicates, Econ. Geol., vol. 1, no. 1, p. 67, 1907.

[55] Vedrödi, V., Der Kupfer als Bestandtheil der Sandböden und unserer Kulturpflanzen, Chem. Zeitung, vol. 17, p. 1932, December, 1893.

[56] Viala, On the action of certain toxic substances upon the vine (Tr.), Revue de Viticulture, nos. 3 and 5, 1894.

[57] Spaeth, R. A., The vital equilibrium, Science, n. s., vol. 43, no. 1110, p. 502, April, 1916.

University of Arizona

Agricultural Experiment Station

Twenty-Seventh Annual Report

For the Year Ending June 30, 1916

(With subsequent items)

Consisting of reports relating to

Administration,
Agronomy, Botany, Plant Breeding,
Horticulture, Animal Husbandry,
Entomology, Chemistry,
Irrigation Investigations, and The Weather

And including a report on

AGRICULTURAL EDUCATION

Tucson, Arizona, December 31, 1916

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AGRICULTURAL EDUCATION

Tucson, Arizona, December 31, 1916

UNIVERSITY OF ARIZONA
AGRICULTURAL EXPERIMENT STATION

GOVERNING BOARD
(Regents of the University)

Ex-Officio

His Excellency, The Governor of Arizona
The State Superintendent of Public Instruction

APPOINTED BY THE GOVERNOR OF THE STATE

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John J. Thornber, A. M.....Botanist
Albert E. Vinson, Ph. D.....Biochemist
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George E. P. Smith, C. E.....Irrigation Engineer
Arthur L. Enger, C. E.....Assistant Engineer
George F. Freeman, B. S.....Plant Breeder
Walker E. Bryan, M. S.....Assistant Plant Breeder
Stephen B. Johnson, B. S.....Assistant Horticulturist
Richard H. Williams, Ph. D.....Animal Husbandman
Walter S. Cunningham, B. S.....Assistant Animal Husbandman
John F. Nicholson, M. S.....Agronomist
Herman C. Heard, B. S. Agr.....Assistant Agronomist
Austin W. Morrill, Ph. D.....Consulting Entomologist
Estes P. Taylor, B. S. Agr.....Director Extension Service
George W. Barnes, B. S. Agr.....Livestock Specialist, Extension Service
L. S. Parke, B. S.....Boys and Girls State Club Agent
Edith C. Salisbury, B. D. S.....Home Economics Specialist
Arthur L. Paschall, B. S. Agr.....County Agent, Cochise County
Charles R. Fillerup, D. B.....County Agent, Navajo-Apache Counties
Alando B. Ballantyne, B. S.....County Agent, Graham-Greenlee Counties
John R. Towles.....Secretary Extension Service
Frances M. Wells.....Secretary, Agricultural Experiment Station

The Experiment Station offices and laboratories are located in the University buildings at Tucson. The new Experiment Station Farm is situated one mile west of Mesa, Arizona. The date palm orchards are three miles south of Tempe (cooperative, U. S. D. A.), and one mile southwest of Yuma, Arizona, respectively. The experimental dry-farms are near Cochise and Prescott, Arizona.

Visitors are cordially invited, and correspondence receives careful attention.

The Bulletins, Timely Hints, and Reports of this Station will be sent free to all who apply. Kindly notify us of errors or changes in address, and send in the names of your neighbors, especially recent arrivals, who may find our publications useful.

Address, THE EXPERIMENT STATION,
Tucson, Arizona.

LETTER OF TRANSMITTAL

To His Excellency, The Governor of Arizona,
Executive Department, Phoenix, Arizona.

SIR: I have the honor herewith to transmit to you the Twenty-seventh Annual Report of the Arizona Agricultural Experiment Station, of the College of Agriculture, University of Arizona, for the fiscal year ending June 30, 1916.

This report is made in accordance with the Act of Congress, approved March 2, 1887, establishing Agricultural Experiment Stations, and the Act of Congress, approved March 16, 1906, known as the Adams Act.

Faithfully yours,

R. B. VON KLEINSMID,
President.

President R. B. von KleinSmid,
University of Arizona,
Tucson, Arizona.

DEAR SIR: I submit herewith the Twenty-seventh Annual Report of the Agricultural Experiment Station for the fiscal year ending June 30, 1916, with subsequent items.

This report relates to the administration of the Station and to the work in Agronomy, Botany, Plant Breeding, Horticulture, Animal Husbandry, Entomology, Chemistry, Irrigation Investigations, and the Weather; and includes a chapter on Agricultural Education.

Very truly yours,

R. H. FORBES,
Dean and Director.

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Fig. 1. Alfalfa in seed near Yuma, second crop, August 27, 1916. First crop, 781 pounds of recleaned seed per acre; second crop, 228 pounds per acre. Total, 1009 pounds of recleaned seed per acre.

Twenty Seventh Annual Report

ADMINISTRATION

By reason not only of abundant crops, but of high prices for agricultural products, and, also, of markets that for the most part readily absorbed the output of grazing ranges and cultivated farms, the agricultural year in Arizona has been one of unprecedented prosperity. This has been true not only of grazing ranges from which have been marketed a surplus of mutton, wool, and beef, and of irrigated farms whose varied products are gradually establishing themselves in sufficient quantity and of such quality as to win recognition in distant markets, but also to an increasing extent is it true that the hitherto little known dry-farming regions of the State are gradually becoming securely established in a peculiar but stable agriculture of their own.

To some extent this general condition of prosperity is doubtless artificial, being due to high prices for many articles directly or indirectly influenced in price by the European war. It is safe to say, however, that the impetus thus given will never be wholly lost since increased agricultural areas, better agricultural organization and improved marketing facilities will maintain a higher level of agricultural prosperity than would otherwise have been possible.

Among the products that have attracted most attention during the year have been Egyptian cotton which, particularly in Salt River Valley, has been developed to the rank of a leading staple. By reason of the Egyptian shortage and of the increasing demand for this cotton for the manufacture of thread, automobile tires, and other purposes where great strength is necessary, the price of the 1916 crop in Salt River Valley reached unprecedented figures. Wool, likewise, because of the destruction of great quantities of wool fabrics in Europe and the curtailment of importations, has advanced to a very high price, with consequently beneficial results to sheep grazing interests on the range. In irrigated sections alfalfa seed, although prices have been moderate, has

been very profitable on account of phenomenal yields, over 1,000 pounds per acre of alfalfa seed having been recorded in the Yuma section. Feeding stuffs in general have been high-priced and readily salable, partly because of the military market along the Mexican line and partly because of considerable areas which have been turned from alfalfa into cotton, wheat and other crops. Grains in general, including wheat, barley, milo maize and other sorghum grains, have produced well and have brought high prices. The cost of feeds, in fact, has reacted somewhat unfavorably upon livestock interests dependent upon them and in some cases has led to shipments of unfinished stock to localities affording cheaper materials with which to finish for market.

The great diversity of crops not only possible in the region, but which year by year are coming into commercial development, continues to be an astonishing feature of the irrigated sub-tropical Southwest. No less than forty-nine such crops are known in the Salt River Valley, which is typical agriculturally of the general region. This diversity is practically equal to that of the State of California or of the thousand mile span of agricultural country lying between the Gulf of Mexico and the Canadian line. The stability and the intensive possibilities of this region, agriculturally considered, are beyond question, a fact which is reflected in the improved conditions which are more and more evident from year to year—better knowledge of agriculture, better farming practice, better co-operation for the solution of agricultural problems, and better agricultural service on the part of public agencies. Responding to this generally improved condition, land values have within the year appreciated considerably and a noteworthy influx of farmers from other sections of the United States is to be observed.

THE EXPERIMENTAL FIELD

Extraordinary diversity characterizes the agriculture of the Southwest not only as to soil conditions, which include extreme alkalinity, diverse physical characteristics and varying chemical composition; and as to rainfall, which ranges from almost nothing to almost humid in amount; but also as to temperature conditions, ranging from sharply frosty in winter to extremely high in summer. Geographically, agricultural locations are distributed from a point about 90 feet above sea level at the southwest corner of the State, where crops can be planted or harvested every month in the year, to an agricultural altitude of 7000 feet, where only quick-growing summer crops can be produced. Dealing therefore with a variety of subjects as great as may be found in

the neighboring State of California or as may be found between the Gulf of Mexico and the Canadian line, demands made upon the Agricultural Staff are very diverse in character. While, however, the State of California has an Agricultural Staff of 130 men to handle their situation, and while the agricultural zone between Canada and the Gulf is served by a whole group of agricultural colleges and experiment stations, Arizona, which, on account of its unique agricultural conditions receives less than the usual amount of help from outside organizations, must handle its problems with a staff at present numbering 21 people. Inevitably, in order to work effectively, this Staff has concentrated its efforts from year to year upon a comparatively small number of problems, laying aside completed work from time to time and taking up new projects as time and funds have allowed.

In this way, the efforts of the Staff having been shaped largely by demands made upon it by the agricultural public, the research work of the Station has for the most part fallen under three general heads relating to (1) the development and effective utilization of agricultural water; (2) intensive cultivation of irrigated lands; and (3) the utilization, by dry-farming methods and by grazing, of lands for which there is but limited water supply. With reference to internal organization this work has been carried on by departments of research classified according to technique as follows: agronomy, animal husbandry, botany, chemistry, entomology, horticulture, plant breeding, and irrigation. Following is a classified list of subjects, exclusive of the 27 Annual Reports, thus far published upon by these departments, comprising 77 Bulletins and 123 Timely Hints for Farmers, besides a considerable list of papers published in scientific journals and a constant output of newspaper articles, addresses and other instruments of information:

Soils, water, alkali and farm management	35
Climate	6
Crops	90
Weeds, insect pests, and plant diseases	23
Irrigation	17
Animal industry and the range	29

This fund of agricultural information constitutes a body of knowledge indispensable at a time when increasing immigration and a quickening in agricultural development has made more urgent the public demand for such information.

This body of agricultural knowledge also serves as a basis for teaching, more particularly in the sub-tropical and semi-arid region which constitutes the field of work. Indeed, until such knowledge had been achieved it would hardly have been possible to establish a satisfac-

tory scheme of agricultural instruction in and for the State. Such a scheme, however, is now under development in the high schools of the State under the provisions of the Vocational Pursuits Law, in the two normal schools, and in the State University. Properly systematized and correlated, these agencies will assist in bringing into common understanding the body of scientific and economic information thus far achieved.

GENERAL PROGRESS FOR THE YEAR

Considerable time on the part of the Agricultural Staff has been devoted to readjustments relating to the occupation of the new Agriculture building and to changes required in connection with the general University administration. Furnishings for the laboratories and offices have been devised and installed, equipment purchased, and at the same time the usual amount of routine work and correspondence has been carried on by the Staff.

THE SALT RIVER VALLEY FARM

An item of considerable magnitude and importance has been the reclamation of the new Station Farm between Mesa and Tempe, Arizona. At the time of its acquisition this property was in a condition of considerable disrepair and a large portion of it was densely seeded to Johnson grass, making a preliminary campaign of reclamation necessary before a scheme of experimental and demonstration work could be installed. Worthless trees and old orchards were grubbed up, useless ditches were plowed in, new fences were built, the two old residence buildings were repaired for temporary use, and a general plan of improvements for the place was drawn up and accurately surveyed. The City of Mesa was permitted in the course of the year to lay an outlet sewer across the southern edge of the place, four inlets being provided, with which it is the privilege of the farm to make connection at a future time if desired. At present, therefore, this property, which lies one mile from the city limits of Mesa, has telephone, gas, electric light and power, and sewerage facilities, and in addition is readily accessible from the State Highway by stage lines connecting with all parts of Salt River Valley. The plan of improvements also calls for a siding and a small station of the Arizona Eastern Railroad, affording additional means by which the public can reach the farm.

Four methods of reclaiming the land from Johnson grass are being tried: (1) Continuous dry fallow, both summer and winter, until the Johnson grass is under control: (2) dry fallow in summer with

winter crops of barley, wheat and oats; (3) winter fallow with intensively cultivated summer crops of Egyptian cotton and Indian corn; and (4) pasturing of ditches and waste ground by means of sheep. In this latter connection the Arizona Eastern right-of-way adjoining the farm, hitherto a jungle of Johnson grass, has been leased and already brought under control by means of sheep.

Fig. 2. The Experiment Station Farm near Mesa, September 3, 1915, showing dense growth of Johnson grass which has since been brought under control.

According to experience gained, the first method entails expense with no income, and the grass is as yet far from exterminated. In (2) the expense of maintaining summer fallow is offset and a clear profit may be gained from the crop of winter grain. In (3) Egyptian cotton has this year yielded a handsome profit in spite of the large amount of hoeing that was done in order to keep the crop entirely free from grass, while the corn just about offset the expense of intensive summer cultivation. In the case of sheep, not only were ditches kept clean with a minimum of expense, but the railroad right-of-way, composed of irregular ground which could not have been handled in any other way, was brought under control not only at a large saving, but with a small profit from the operation. At present it appears that a combination of sheep and intensive cultivation will take care of the Johnson grass problem in southern Arizona much more profitably than by the old expensive method of continuous dry fallow.

Experimental acres of alfalfa, lettuce, and various winter growing

green manuring crops have been planted on the northeastern forty acres of the farm for the season of 1917, while the scheme of reclamation outlined above is being continued upon the other weedier portions of the place.

THE YUMA DATE ORCHARD

At the Yuma Date Orchard horticultural plantings have been continued between the rows of date palms, plant breeding work has been continued on a portion of the place, and the new block for horticultural planting has been leveled and enriched by means of two crops of

Fig. 3. Sudan grass at Yuma, August 28, 1916. One week's difference in age of two plots.

tepary beans ploughed under in preparation for fruit trees the following season. This garden continues to be one of our best kept agricultural properties, and the new Warrenite roads which now pass the property on the south and west sides, and which carry practically all of the travel between Yuma and the lower valley, contribute to its value as an object lesson and as a source of information to the rural population. The Yuma property has been improved by means of new fencing and additions to the residence building during the year.

THE TEMPE DATE ORCHARD

Improvements to the residence at the Tempe Date Orchard have been made; and the old structures, used as packing sheds, have been

replaced by a new structure which contains rooms for ripening, packing and displaying the product of the orchard. The crop of 1916 was very much inferior to that of 1915, not only because the trees set less than half the number of clusters of fruit, but also because a heavy rain early in September caused a large portion of the crop from many varieties to sour. The total sales from the crop of 1915 amounted to $4734.10, while those from the crop of 1916 amounted to $1563.79. These two years' experience, one of them the most prosperous and the other the most unsatisfactory in the history of the orchard, afford us excellent means of judging the vicissitudes to which the crop in this climate is liable and enables us to strike a fair average of performance for a number of the more promising varieties of dates at the orchard.

A feature of the year's work with dates has been the installation on the Mesa Farm of a propagating house for date suckers according to the plan developed by the U. S. Department of Agriculture in the Coachella Valley, California. This house, the sides of which are constructed of boards coated with paper roofing and the top of which consists of 10 oz. canvas, affords in summer a hot and humid atmosphere and a diffuse light evidently very favorable to the rooting and growth of offshoots, while in winter the newly rooted plants, which are very susceptible to cold, are protected from frost. This method, which at least affords success in the rooting of suckers, solves what has thus far been a most serious problem in connection with the date industry, and puts horticulturists in position to propagate much more rapidly desirable varieties of palms.

THE DRY-FARMS

The dry-farms at Prescott and Cochise have had a fairly successful year, particularly the one at Cochise in the Sulphur Spring Valley, where the summer rains were somewhat more favorable than usual and afforded excellent crops of Tepary beans, milo maize, feterita, and Sudan grass. A silo was constructed during the year and filled with silage products on the place. The year's work, indeed, has seemed to demonstrate a successful scheme of agriculture for the Sulphur Spring and similar valleys in the Southwest.

The salient features of this plan are, the most effective use of rainfall, quick growing drouth resistant crops, silos, livestock and the skillful supplemental use of grazing range, dry-farming and irrigating resources available within the region. The supplemental use of the various resources referred to is of particular importance to the dry-farmer in this region, for he must combine grazing, rainfall and

ground-water resources in a manner to reap the benefits and avoid the disasters incident to the use of any one of these alone. The stockman, relying upon the grazing range alone, is subject to disaster by drought. The dry-farmer, relying upon rainfall alone, will likewise often fail through want of an adequate water supply. The pump irrigator alone will fail because he cannot afford the cost of his pumped water supply; but upon the combined resources of the grazing range, the dry-farmer and the irrigator, a scheme of agriculture can be built up that combines all of the advantages mentioned and avoids the disaster almost certainly resulting from dependence upon any one of them alone. The grazing range, for instance, with its rich burden of green feed during the rainy season, supplements the dry-farmer's silo; and the water supplied by the pump irrigator at times when water must be had to start or save a crop, supplements the rainfall upon which the dry-farmer must mainly rely. This cooperation between cheap range feed, dry-farm forage supply available as silage, and pumped or stored water supply used in time of need, together with a scheme of livestock adapted to the best use of forage supplies, points the way towards the utilization of hundreds of thousands of acres of lands in a region of which it was formerly said that it could only be farmed by means of a copious irrigating water supply.

THE NORTHERN ARIZONA DRY-FARM

Operations at the dry-farm near Snowflake, Arizona, were discontinued because of the great distance from supervision and the difficulty, therefore, in securing satisfactory returns for the money expended upon the work. Continuation of dry-farming operations at a third location in the State has not as yet been decided although it is recognized that an agricultural region of higher altitude and consequently peculiar conditions exists between 5000 and 7000 feet elevation. This region is distinguished by its short summer growing season and is limited to such quick growing crops as early potatoes, oats, certain varieties of corn, vegetables, and some of the deciduous fruits.

REQUIREMENTS FOR FUTURE PROGRESS

The physical properties of the several departments of the College of Agriculture are at this time fairly complete and satisfactory, consisting not only of office and laboratory facilities in the Agriculture Building on the University Campus, together with adjacent gardens and the University Farm, but also consisting of outlying cultivated tracts—the

Station Farm near Mesa, the cooperative date orchard near Tempe, the intensively cultivated garden at Yuma and the dry-farms near Prescott and Cochise, respectively. This organization of facilities affords not only the advantage of affiliation with the general University organization, but also affords wide contact with the diverse agriculture of the State.

As pointed out in the preceding paragraphs, the personnel of the Station is small in proportion to the diversity of the agriculture which it serves, and as opportunity offers personnel should now be built up in order to make the best use of the physical facilities available. At this time particularly executive assistance is needed in order that systematic and thorough administration of the affairs of the College of Agriculture and Experiment Station may be maintained. This is particularly true in connection with the outlying farms situated at a distance from the University Campus, which are increasing in the amount and complexity of operations carried on. It is necessary in this connection to maintain suitable records of work done, to install proper systems of cost accounting in connection with crop demonstrations, to keep track of public needs and wishes in connection with experiments undertaken, and in other ways provide for the greatest possible usefulness and efficiency of this work. Within the campus itself there is the same need for more time in which to study the requirements, the possibilities of usefulness and the actual efficiency of departments of work. These objects can only be obtained by means of assistance sought for, a fact to which the attention of our authorities has been called both in written reports and in verbal communications, for several years past. In view of the opportunity for economic demonstrations of farm crops which exists upon all of the farms at this time, it is recommended that provision be made for the assistance mentioned along farm management lines, and appointments to this effect are at this time urged. Properly organized, such assistance will also relieve the scientific staff of a good deal of executive work with which it is at this time burdened and enable its members to devote themselves more effectively to research, teaching, and extension activities expected of them by the agricultural public.

PERSONNEL

The personnel of the Agricultural Staff has remained substantially the same during the year, but with several shifts between different departments of service.

For a period of about ten months the Director was on leave of absence in Riverside, California, completing a long standing research relating to the mining waste problem in certain irrigated districts in Arizona, and, incidentally, studying the agriculture of a district resembling southern Arizona but older in experience and more highly developed in its methods. Professor G. F. Freeman assumed the duties of Acting Dean and Director of the College of Agriculture and Agricultural Experiment Station for the time mentioned, and it is under his direct supervision, with the collaboration of the Director, that the work of the year has been accomplished. A. M. McOmie, for six years Assistant Agriculturist in the Station, went into commercial work January 1, 1916, and was succeeded by Professor John F. Nicholson, of St. Louis, as Agronomist, and Mr. H. C. Heard, of Moscow, Idaho, as Assistant Agronomist. Mr. Leonhardt Swingle, for one year Assistant in Plant Breeding, went into commercial work January 1, 1916, and was succeeded by Mr. Walker E. Bryan, of Alabama. Mr. C. R. Fillerup, foreman of the dry-farm at Cochise, was promoted to be County Agent in the Extension Service in Navajo County. Mr. L. L. Bates, foreman of the Prescott dry-farm, went into commercial work near Prescott, and was succeeded by Mr. Hyrum Dana. Mr. D. C. Aepli, of the old Station farm near Phoenix, was transferred to the Yuma garden; and Mr. C. J. Wood, formerly of the Yuma garden, was transferred to the foremanship of the new Station farm near Mesa. Miss Helen M. A. Miller, for several years Librarian and Secretary, was succeeded by Miss Frances M. Wells as Secretary. Mr. J. A. Armstrong, Farm Advisor for Maricopa County, resigned June 1, 1916, to go into commercial work, and his place has not as yet been filled.

Mr. Stanley F. Morse, for three years Superintendent of Extension also resigned August 15, 1916, to go into commercial work, and he was succeeded by Professor Estes P. Taylor as Director of the Extension Service.

PUBLICATIONS

Publications for the year, including Annual Reports, Bulletins, Timely Hints for Farmers, and scientific papers are as follows:

Bulletin 77, June 1, 1916. Practical Fig Culture in Arizona.
—By W. H. Lawrence.

Twenty-sixth Annual Report, December 31, 1916. —By the Station Staff.

Timely Hints for Farmers:

No. 111. September 1, 1915. Irises for Southwestern Gardens.
—By J. J. Thornber.

No. 112. October 1, 1915. Garbanzo Culture in Arizona.
—By R. H. Forbes and Stanley F. Morse.
No. 113. December 1, 1915. Orchard Heating. —By Donald F. Jones.
No. 114. March 1, 1916. Producing Guaranteed Eggs. —By R. H. Williams.
No. 115. February 1, 1916. Infectious Abortion in Cows.
—By R. H. Williams.
No. 116. May 1, 1916. Sugar Cane in Arizona —By A. M. McOmie
No. 117. May 1, 1916. Vines for Shade and Ornamental Planting.
—By J. J. Thornber.

Papers published in scientific and technical journals:

The Utilization of Groundwater by Pumping for Irrigation
Trans. International Engineering Cong., 1915. Waterways and Irrigation.
Volume ....., pp. 414-444. —By G. E. P. Smith
Duty of Water in Irrigation.
Ibid, pp. 494-496. —By G. E. P. Smith.
Duty of Water and Evaporation-rate.
Twenty-second International Irrigation Cong., 1915.
—By G. E. P. Smith.
Composition of Salton Sea Water, June 10, 1916.
Carnegie Institution of Washington, Year Book No. 15, 1916, p. 88.
—By A. E. Vinson.
Quality *vs.* Number in Range Cattle.
Arizona Cattle Growers' Assn., Ninth Annual Report.
—By R .H. Williams
Registered *vs.* Scrub Sires on the Range.
The American Hereford Journal, June 1, 1916. —By R. H. Williams.
The Practical Application of the Ferris Stock-raising Homestead Bill to Our Western Grazing Ranges.
Proc. Nineteenth Ann. Convention Amer. Live Stock Assn., 1916, p. 116.
—By J. J. Thornber.

FINANCIAL

Financial resources for the year ending June 30, 1916, were as follows:

Hatch Fund, from the U. S. Treasury			$15,000.00
Adams Fund, from the U. S. Treasury			15,000.00
Sales fund balances from 1914-15		$ 2,022.12	
Sales funds 1915-16 as follows:			
Salt River Valley Farm, Mesa	$ 613.35		
Yuma Date Orchard	824.47		
Tempe Date Orchard	4,734.10		
Prescott Dry Farm	200.00		
Sulphur Spring Valley Dry Farm	21.77		
Hatch Sales Fund	2,368.05	8,761.74	
		$10,783.86	
Less remittances to			
State treasury	1,941.61		
Balances on hand	536.31	2,477.92	8,305.94
State appropriations:			
Balances from 1914-15			507.73

Appropriations for 1915-16:		
Date Palm Orchards	$ 3,500.00	
Sulphur Spring Valley Dry Farm	4,160.00	
Dry Farming Sec. 26	3,000.00	
Dry Farming Section 27 A	4,600.00	
Northern Arizona Dry Farm	3,200.00	
Yuma Horticultural Station	700.00	
Plant Introduction and Breeding	3,000.00	
Underflow Investigation	2,750.00	
Salt River Valley Farm	3,000.00	
Printing and Binding (Agri.)	1,500.00	
Maintenance	9,241.06	
	$38,651.06	
Less balances to 1916-17	5,105.88	33,545.18
		$72,358.85

A statement of expenditures by schedules and by funds is also submitted herewith.

R. H. FORBES,
Director.

EXPENDITURES BY FUNDS AND SCHEDULES FOR THE YEAR ENDING JUNE 30, 1916

Abstract	State Appropriations	Sales Funds	Hatch Fund	Adams Fund	Total
Salaries	$ 9,841.26	$.....	$ 7,276.98	$10,647.39	$27,765.63
Labor	6,833.37	2,974.27	5,199.46	1,281.05	16,288.15
Publications	1,637.99	.....	4.85	(Omit)	1,642.84
Postage and stationery	.....	132.11	615.21	57.53	804.85
Freight and express	44.43	108.19	7.12	111.00	270.74
Heat, light, water and power	.....	548.50	126.91	30.75	706.16
Chemicals and laboratory supplies	.....	.....	111.72	254.18	365.90
Seeds, plants and sundry supplies	2,769.38	895.65	244.53	146.07	4,055.63
Fertilizers	158.56	7.31	91.75	185.38	443.00
Feeding stuffs	454.33	9.45	67.90	185.40	717.08
Library	.....	.....	13.50	1.35	14.85
Tools machinery and appliances	662.37	590.95	311.92	141.12	1,706.36
Furniture and fixtures	4,297.33	133.35	31.83	5.00	4,467.51
Scientific apparatus and specimens	.....	278.56	26.50	995.36	1,300.42
Livestock	584.71	18.00	2.00	.....	604.71
Traveling expenses	1,897.51	679.95	620.45	599.43	3,797.34
Contingent expenses	32.50	318.93	20.00	.....	371.43
Building and land	4,839.17	1,610.72	227.32	354.60	7,031.81
Balance	.....	.....	.05	4.39	4.44
	$34,052.91	$8,305.94	$15,000.00	$15,000.00	$72,358.85

AGRONOMY

Experimental work in agronomy for the year has included operations upon the old Experiment Station farm near Phoenix previous to removal from that place June 30, 1916; the initiation of work upon the new Experiment Station farm between Tempe and Mesa; dry-farming operations on the Prescott Dry Farm near Prescott, and on the Sulphur Spring Valley Dry Farm near Cochise, Arizona. This work has therefore included experiments and demonstrations on a wide variety of soils under irrigation and by dry-farming, and with a considerable range of atmospheric conditions. A good deal of information has been obtained relating to standard crops—wheat, barley, oats, alfalfa, beans, and sorghum grains, as well as with some new crops in the region. The work finishing operations at the old farm near Phoenix is reported in considerable detail. The plan of reclamation at the new farm near Mesa is outlined and a table of the first season's results is submitted. A summary for the work done at the Prescott and Sulphur Spring Valley Dry Farms for the year is also given.

PHOENIX FARM

The experimental crop work on the Phoenix Farm this year was limited to small grains, flax, and alfalfa. The work was limited on account of the intention to discontinue experimental operations on this farm at the end of the fiscal year 1916.

The character of the soil is designated as Maricopa sandy loam. Little attention has been paid to the maintenance of fertility in previous years, hence the quantities of the crops are below the average. Since, however, most of the experiments were variety tests, the relationship between yields of grains tried can be quite accurately observed.

CROPS GROWN

Wheat: The work for the year demonstrated the superiority of fall over spring planting. All of the 21 varieties tested this year were planted in the fall. All seed used in the tests was treated with formalin for smut. No introduction of new varieties was made, hence all seed of this year's plantings were grown on the farm last year.

The season was such that very little rust appeared. The Early Baart and the Little Club were the only varieties showing this disease in injurious amounts. The following table gives the varieties in the order of their production, and also shows dates of planting, harvesting, irrigating and rate of seeding per acre.

TABLE I. VARIETY OF TESTS

Variety	Date planted	Rate seeding per acre	Date harvested	Yield per acre	Dates irrigated
		pounds		pounds	
Early Baart	11-15-15	75-80	5-18-16	2460	11-22-15— 2-11-16
White Australian....	11-15-15	75-80	5-18-16	2420	11-22-15— 2-11-16
Little Club	11-15-15	75-80	5-12-16	2380	11-22-15—12-11-15—4- 5-16
Marquis ...	12-20-15	75	6- 6-16	2128	11-18-15— 2-11-16—3-13-16
Koffoid ...	11-15-15	75-80	5-29-16	2060	11-22-15— 2-11-16
Wild Wheat	11-29-15	75-80	5-23-16	2060	11-18-15—12-11-15—4- 5-16
Marquis ...	11-15-15	75-80	5-22-16	1900	11-22-15—12-11-15—2-11-16
Sonora ...	11-29-15	75-80	5-18-16	2060	11-18-15—12-11-15—3-13-16
Kubanka...	11-29-15	75-80	5-23-16	1820	11-18-15—12-11-15—4- 5-16
Red Chaff	11-15-15	75-80	5-31-16	1900	11-22-15—12-11-15—3-13-16
Red Fife...	11-26-15	75-80	5-29-16	1800	11-18-15—12-11-15—3-13-16
White Australian....	11-29-15	75-80	5-29-16	1700	11-18-15—12-11-15—2-11-16
Arinaviar ..	11-29-15	75-80	5-31-16	1700	11-18-15—12-11-16
Macaroni ..	11-15-15	75-80	5-22-16	1680	11-22-15— 2-11-16
Crimean ...					
C. I. 1435..	11-29-15	75-80	5-31-16	1660	11-18-15—12-11-15—3-13-16
Blue Stem	11-15-15	75-80	5-22-16	1660	11-22-15— 2-11-16
Defiance ..	11-15-15	75-80	5-23-16	1640	11-22-15— 2-11-16
Turkey Red	11-15-15	75-80	5-29-16	1640	11-22-15— 2-11-16—3-13-16
Bulgarian..	11-29-15	75-80	5-31-16	1260	11-18-15—12-11-15—2-11-16
Red Russian	11-15-15	75-80	6- 6-16	1200	11-22-15— 2-11-16—4- 5-16
Kharkov...					
C. I. 1442..	11-29-15	75-80	5-31-16	1100	11-18-15—12-11-15—2-11-16
Crimean—					
C. I. 1437..	11-29-15	75-80	5-31-16	1040	11-18-15—12-11-15—2-11-16
Buffum No. 17.....	11-26-15	75-80	6- 6-16	1040	11-18-15—12-11-15

It will be noted from Table I that Early Baart gave the highest yield of grain. White Australian, Little Club and Marquis were not far behind. Early Baart is quite generally grown throughout the Salt River Valley, and meets the demands of the millers generally. With this taken into consideration its yielding capacity would recommend it highly as a standard variety for this section. Marquis is a considerably better milling wheat than Early Baart, but so long as the local market will not pay higher prices for it than it does for the softer wheats, and the local production is not equal to the local demand, Early Baart can be profitably grown as the standard variety.

The hard winter and durum wheats did not show up as well as the varieties mentioned above, and it is doubtful if it would be advisable to encourage their production at this time.

Two plats of Marquis, planted November 15 and December 20, respectively, gave a difference of 228 pounds per acre in favor of the later planting. This can be explained by the better seed bed conditions at the later planting date. The November planting was irrigated by

an application of water seven days after sowing, which is a bad practice. The December planting was made in a seed bed which had received water November 18 and December 11, respectively. The latter irrigation placed the seed bed in excellent condition for planting nine days later.

The two plats of White Australian show a difference of 720 pounds per acre in favor of the November 15 planting as compared with the November 29 planting. There were two factors that may have had a bearing on these results. The November 29 planting was made on a more gravelly plat than the other, and the seed for the November 15 planting was home grown, while that for the other came from Yuma. Seed should be locally grown, when of good quality, on account of the influence of acclimatization. In the case of the heavier yield the crop was irrigated subsequent to seeding, as it was with several of the other plats, but in spite of this improper practice the yield was greater than the White Australian grain on the poorer soil.

Barley: Nine varieties of barley were included in the variety test plats this year. All of these were sown in the fall. No spring planting was made on account of previous year's trials showing the fall planting superior to the same varieties planted in the spring.

Table II gives the varieties in the order of yields per acre, and also indicates the dates of planting, harvesting, irrigating, and rate of seeding per acre. All of the seed was treated for smut with formalin, which resulted in there being no smutted grain in any of the plats. All of the seed was grown on the farm last year.

TABLE II. VARIETY TESTS OF BARLEY

Variety	Date planted	Rate seeded per acre	Date harvested	Yield per acre	Dates irrigated
		pounds		pounds	
Beldi ...	11-26-15	75-80	5- 6-16	2580	11-18-15—12-11-15—3-13-16
Tennessee Winter..	11-29-15	75-80	5-12-16	2200	11-18-15—12-11-15
Chevalier	11-29-15	75-80	5-12-16	2160	11-18-15—12-11-15—4 -5-16
California 6-Row..	12-27-15	90	5-13-16	2000	12-11-15— 3-13-16—4- 5-16
Mariout	11-26-15	75-80	5- 8-16	1840	11-18-15—12-11-15—4- 5-16
California 6-Row..	12-26-15	75-80	5- 8-16	1680	11-18-15—12-11-15—2-11-16
Black Hull less....	11-26-15	75-80	5- 8-16	1440	11-18-15—12-11-15—3-13-16
Day....					
Brewing	11-26-15	75-80	5-11-16	1440	11-18-15—12-11-15
Utah Winter.....	11-29-15	75-80	5-31-16	1220	11-18-15—12-11-15—3-13-16
White Hulless	11-26-15	75-80	5- 8-16	1060	11-18-15—12-11-15—3-13-16

Beldi, a common bearded variety, gave the best yield. Tennessee Winter barley, another bearded type, was second, and Chevalier, a 2-rowed bearded barley, was third. Last year the Utah Winter barley was the heaviest yielder out of ten varieties planted in the spring, but proved a very poor producer when planted this year in the fall. The California 6-row barley was planted on two dates, November 26 and December 27, respectively. The December planting gave a higher yield by 320 pounds per acre. The November 26 plat was badly infested with burr clover which may have accounted for some of the difference in yield. Since much of the barley grown in Salt River Valley is used for hay, it is highly desirable to secure a beardless variety. White Hulless has a hooded spike, and it was hoped that it might prove sufficiently productive to encourage its general introduction. Its yield of 1060 pounds per acre placed it lowest in the list. Further work is desired along this line either with this variety or some other possessing the advantage of beardless spikes.

Oats: Nine varieties of oats were sown in the fall. The previous year's tests gave much better yields for the fall planted plats as compared to those planted in the spring. All seed was home grown, except one plat of Red Algerian which came from Yuma and gave 580 pounds per acre better results than the home grown Red Algerian seed. All of the seed was treated for smut with formalin, which resulted in practically no loss from this disease.

Table III gives the varieties tested arranged according to yields per acre. The table also shows dates of planting, harvesting, irrigation and rate of seeding per acre.

TABLE III. VARIETY TEST OF OATS

Variety	Date planted	Rate seeding per acre	Date harvested	Yield per acre	Dates irrigated 1915		1916	
		pounds		pounds				
San Saba....	11-15-15	75-80	5-23-16	2900	11-22	12-11	3-13	
Texas Red..	11-26-15	75-80	5-17-16	2680	"	"	...	4-5
Australian Rust Proof	11-15-15	75-80	5-17-16	2400	"	"	...	"
Alberta Red	11-15-15	75-80	5-23-16	2060	"	"	...	...
Red Algerian	11-29-15	75-80	5-31-16	2020	"	"	...	...
Calif. Red..	11-15-15	75-80	5-11-16	1680	"	"	...	...
Boswell Black Winter....	11-29-15	75-80	5-31-16	1100	"	12-11	"	...
Red Algerian	11-26-15	75-80	5-17-16	1440	"	"	...	"
Black Eagar	11-15-15	75-80	5-23-16	1000	"	"	...	...
Texas Red..	12-29-15	75	5-24-16	800	"	.....	2-11	"

The Texas Red oats gave the highest yield of grain last year but was surpassed by San Saba this year. The Australian Rust Proof

proved a very good producer this year. Texas Red Oats were planted November 26 and December 29, respectively. The latter planting was practically a failure with only 800 pounds production per acre.

With a production of 2900 pounds of oats per acre there is no question as to the place of this grain in Salt River Valley or other irrigated sections of the State. For feeding upon the farm to work horses during the hot season they are superior to barley, and should find a place in limited acreage on every farm.

Rye, emmer and spelt: One plat of rye was planted December 9, 1915, at the rate of 50 pounds per acre. This was irrigated four times, including the application of water prior to sowing for the purpose of putting the seed bed into shape. The crop was harvested May 23, 1916, giving a yield of 1200 pounds per acre. There is little profit in growing rye with this low production. This, in view of the limited market for this grain, makes it a questionable crop for the irrigated sections of the State.

Only one plat of Black Winter emmer was tried this year. This was sown November 26, 1915, at the rate of 75 to 80 pounds per acre. The stand came 90 per cent about two weeks after planting. The plat was irrigated eight days previous to sowing, and again on December 11. Harvesting was done May 31, 1916, showing a yield of 1540 pounds per acre.

Emmer produced some 3600 pounds per acre last year on the farm, but even with such yields it is doubtful whether it is a paying crop to grow on the highly improved irrigated lands of the State. It has a place in the crop system of the dry farms of the State, and is proving very valuable there. With good crops of barley, oats, and wheat, the irrigation farmer fills his needs for small grain crops, and will find them much more satisfactory to grow than emmer.

Only one plat of spelt was tried this year. This was sown November 26 on land irrigated eight days previous. Seeding was done at the rate of 75 to 80 pounds per acre, which gave an excellent stand. The crop was irrigated once after seeding, and harvested June 6, 1916. The yield was 1200 pounds per acre. There is no reason for encouraging the growing of spelt on our irrigated farms. Other and more profitable crops should be adopted on such highly developed and expensive land.

Field peas, vetch and chick-peas: Two varieties of field peas—Colorado Stock and Canadian—were planted November 29, with results so poor that the crops were not harvested. Spring and Winter vetch planted December 9 failed to germinate. The chick-peas planted

November 15 made a very meagre growth, failed to form any seed, and were plowed up as a failure. More extensive investigations are planned for next year with these legumes as forage and green manuring crops. Our soils are deficient in humus, and it is particularly desirable that a proper winter legume be found for green manuring purposes. The cause of the above failure will be studied, and if possible methods found to grow them successfully in Arizona.

Approximately seventeen acres of the farm were devoted to alfalfa. This was cut twice from January 1 to July 1, yielding the following amount of dry hay:

First cutting April 5 to 10. Yield 33495 lb.
Second cutting May 22 to 25. Yield 48325 lb.
Average for 2 cuttings, 2.4 tons per acre.

The alfalfa was cultivated with a spring-tooth harrow January 10. It was irrigated on the following dates: February 22, March 20, April 21, May 4, and May 17.

As stated before, all experimental work on the Phoenix Farm terminated July 1, 1916. On that date the alfalfa was about ready to cut for the third time, but was left for the lessee, who took immediate possession.

Flax: The flax testing plats were continued again this year, using the same varieties tested last year and a considerable number of others furnished by the U. S. D. A. This work is done in cooperation with the Department of Agriculture under the immediate supervision of Charles H. Clark, Assistant Agronomist in charge of Flax Investigations. Six varieties, North Dakota Resistant, Select Russian, Smyrna, Punjab, Boulga, and Soddo Brown, were grown in one-fourth acre plats. In these seeding was made in 6-inch drill rows.

Table IV gives the results of these plantings together with information as to date of seeding, harvesting and irrigation.

TABLE IV. FLAX IN ONE-QUARTER ACRE PLATS

Variety	Gov't C. I. No.	Date planted	Date harvested	Yield per acre	Dates of irrigation
				bushels	
N. D. Resistant	13	12-24	5-11	9.6	12-11 2-11 2-29 3-13 3-21 4- 1 4-20 5- 3
Select Russian	3	12-24	5-11	8.6	12-11 2-11 2-29 3-13 3-21 4- 1 4-20 5- 3
Smyrna	30	12-24	5-25	10.4	12-11 2-11 2-29 3-13 3-21 4- 1 4-20 5- 3
Punjab	20	12-24	5-25	7.1	12-11 2-11 2-29 3-13 3-21 4- 1 4-20 5- 3
Boulga	37	12-24	5-25	10.0	12-11 2-11 2-29 3-13 3-21 4- 1 4-20 5- 3
Soddo Brown..	38	12-24	5-25	8.6	12-11 2-11 2-29 3-13 3-21 4- 1 4-20 5- 3

Some thirty varieties were grown in nursery rows and cultivated eight times. Some of the varieties were planted on two different dates, November 8 and December 22, respectivly. Table V shows the results of these test rows, as well as dates of planting and harvesting.

TABLE V. FLAX IN NURSERY ROWS

Variety	Gov't C. I. No.	Date planted*	Date harvested	Yield per acre
				bushels
Tashkent	11	11- 8	6- 9	7.87
Tashkent	11	12-22	6- 9	10.55
Kashgar	50	11- 8	6- 9	7.92
Turkish	7	11- 8	6- 9	5.21
Smyrna	30	11- 8	6- 9	8.55
Smyrna	30	12-22	6- 9	5.11
N. D. Resistant	13	11- 8	5-12	4.91
Matania	34	11- 8	6- 1	3.24
Hoshangabad	40	11- 8	6- 1	5.31
Hoshangabad	40	12-22	6- 9	11.63
Punjab	20	11- 8	6- 1	8.37
Punjab	20	12-22	5-23	13.64
Jalaun	21	11- 8	6- 1	7.18
Jalaun	21	12-22	6- 9	12.26
Benares	28	11- 8	6- 1	6.08
Benares	28	12-22	5-23	4.86
Soddo White	36	11- 8	6- 1	6.97
Soddo White	36	12-22	6- 9	12.65
Soddo Brown	38	11- 8	6- 9	5.95
Canadian La Plata	26	12-22	6- 1	11.94
Nova Rossick	27	12-22	6- 1	14.96
Fargo Common	18	12-22	5-23	11.79
Hay's Seed Flax	16	12-22	5.23	6.82
Russian	19	12-22	6- 9	9.26
Select Russian	3	12-22	5-23	6.82
Select Russian	1	12-22	6- 9	6.48
Select Russian	45	12-22	6- 9	9.97
Select Riga	2	12-22	5-23	6.08
N. D. Resistant	14	12-22	5-23	9.26
Kazan	4	12-22	5-23	9.00
Primost	12	12-22	6- 9	7.20
Sethbridge Golden	23	12-22	6- 9	8.83
Williston Golden	25	12-22	5-23	10.08
Mundjar	35	12-22	6- 9	7.91
Boulga	37	12-22	6- 9	8.10
Metcha	39	12-22	6- 1	7.70

*All rows planted November 8, 1916, were irrigated 10-26, 2-18, 3-7, 3-21, 4-20 and 5-3. Those planted December 22, 1916, were irrigated 12-11, 2-8, 3-7, 3-16, 4-3, 4-20 and 5-3.

This work was intended only as a test of varieties; however, those varieties planted at two dates, namely, November 8 and December 22, with but two exceptions gave better results with the later planting. All of the flax was badly infested with the false chinch bug at heading time. Frequently all of the bolls on a plat were intensely festooned with these sucking insects. The result of these ravages must have been

very instrumental in cutting the yield, and also in lessening the weight of seed per bushel.

All of the varieties mentioned in Table V will be continued in test plats and rows another year. Conclusions should not be drawn, therefore, until a more extensive trial has been made. In general, it can be said that flax growing for seed has indications of being a profitable industry for our irrigated valleys in Arizona.

THE NEW EXPERIMENT STATION FARM

The University assumed direct management of the new Experiment Station Farm, near Mesa, on July 1, 1915. The place was rather heavily infested with Johnson grass, the fences were old and run down, and in many places the lay of the land for irrigation needed much improvement. Accordingly the main efforts on this farm have been directed toward improving the irrigation system, fencing, eradicating Johnson grass, and bettering the general appearance of the place. It has not been considered advisable to attempt much experimental work here until the Johnson grass is brought well under control, and the irrigation can be accurately handled.

THE JOHNSON GRASS EXPERIMENT

The north half of the east 80 acres of the farm was quite free from Johnson grass when the Experiment Station took charge. Aside from this the entire remaining 120 acres were badly infested. Half the Johnson-free portion was planted to wheat and half to alfalfa. Any stray grass in these fields was destroyed by hand digging.

In the south half of the east 80 acres, a strip which had been in wheat in the spring of 1915, was set aside to be dry fallowed. It was plowed in August, of that year, and worked down later in the fall with a disc and harrow. A luxuriant crop of volunteer grains came up with the winter rains, and in many places a perfect stand was found. This heavy growth soon seriously depleted the soil moisture, and the Johnson grass growth in the spring of 1916 was very meagre, being confined for the most part to seedlings. This field was again plowed in April. The land was very dry and no appreciable growth of Johnson grass was noted until after the summer rains began. At this time, as before, seedlings were most in evidence. A particularly hard rainstorm in early September soaked the ground quite thoroughly, and gave the seedlings a fresh start. In order to control these the entire field was plowed and disked the third time. The land was in very clean shape, preparatory to seeding to grains in December, 1916.

The west 80 acres was divided into five fields, three of which contained 20 acres each, and two 10 acres each. Four methods of eradication were tried out on these fields: close pasturing with sheep, intensive cultivation of intertilled summer crops, dry fallow in summer followed by grain in winter, and continuous dry fallow.

The first field contained 20 acres. It was plowed in September and October of 1915 when very dry and hard, leveled and bordered in November, and seeded to barley in December. The dry plowing in 1915 served to check seriously the Johnson grass, and as a result very few plants were showing above the grain while the latter was still standing. The grain was bound about the middle of May, 1916, and the ground was held dry until the middle of June, at which time about 275 sheep were turned in on it. Between the time of removal of the grain and coming of the sheep, a considerable growth of Johnson grass had sprung up uniformly over the field. None of this was allowed to mature seed. After the sheep came, the field was irrigated at frequent intervals in order to force as rapid a growth of Johnson grass as possible. The sheep kept it eaten very close to the ground, and, as a result, the propagating rootstocks of the grass were showing marked lack of vigor by the fall of 1916. In the middle of November, 1916, the land was prepared and seeded to barley for pasture, and it is believed that by the end of another summer the Johnson grass of this field will either be almost totally destroyed or well under control.

The remainder of the west 80 acres had been in grain sorghums for a number of years, and the University did no work to eradicate Johnson grass on it in 1915, except to mow some of it and burn over some of the worst of it. Some of the laterals were so badly infested that it was deemed advisable to fill them with straw and burn them out.

The first 10 acres of this part was plowed in February preparatory to putting into Egyptian cotton. In order to make this land irrigate perfectly it was all replowed once and part was replowed a second time. In this way the grass was constantly disturbed until the middle of April. The cotton was not planted until this late date on account of the work necessary to level the land properly. A cultivator equipped with 8-inch sweeps was put to work in this field in the latter part of April, and was kept going whenever any grass appeared above the surface of the ground. The weeds in the rows were removed by hand hoeing. By the time the cotton had become large enough to shade the ground very little Johnson grass was appearing, and in the latter part of the season the few plants left were almost all from seeds which, presumably, were brought in by the irrigating water.

The next 10-acre field was treated in a similar manner, except that it was planted to Sacaton June corn in the middle of July. This field was first plowed in April. The Johnson grass was kept down by the cultivator until June, when the field was replowed to facilitate leveling. After being put in corn it was again kept under control by the cultivator and by hand hoeing. The condition of the Johnson grass at the time of the first frost was much the same as that in the cotton.

The remaining 40 acres are divided into two 20-acre fields, both of which have had the same treatment to date. One of these is to be planted in grain in December, 1916, and the other is to be continuously dry fallowed. All of this land was plowed in March and April, and replowed in August. It was disced in July and September, and after the latter operation was run over twice with a "Cyclone" weeder. The fight against Johnson grass on these two fields, while it has unquestionably borne good results, has probably been the least effective of that on any of the fields, and there are a number of roostocks remaining which have approximately normal vigor. An exceedingly heavy rain late in the summer and occasional accidental leaking of irrigation water have been largely responsible for reducing the efficiency of the Johnson grass control method on these fields. It appeared advisable on one occasion to pasture sheep for a short time on these fields, owing to an increased growth of the grass due to heavy rains. The value of this pasturage from each field was estimated at $4.60 per acre and is the only returns we have received from the fields during the experimnts.

WHEAT AND ALFALFA

As mentioned above, the north half of the east 80 acres was put into wheat and alfalfa. This was run under commercial farming conditions and was in no sense experimental in its nature, though it had its value for demonstration purposes. This 40-acre tract had been in grain in the spring of 1915. It was plowed dry in August of that year.

Twenty acres were prepared for irrigation in November, 1915, and sown to Early Baart wheat on November 25, at the rate of 60 pounds per acre. The soil is very fertile, and a heavy stand of very high wheat was the result. Danger of lodging made it inadvisable to give it all the water it needed for complete filling. A very slight damage was caused by rust, and a considerable amount of trouble was experienced from lodging. The yield was slightly more than 1900 pounds of grain per acre, and, in addition, 27 tons of straw were sold.

The wheat stubble on 9 acres was plowed up in July and early

August, 1916. This land was planted to Sudan grass in the middle of August at the rate of 20 pounds to the acre. This was cut October 28, and an estimated yield of 30 tons of cured hay was obtained.

Because of space taken up by a roadway, and by fences, the actual size of the alfalfa yield was slightly less than 14 acres. After having been summer plowed dry, as given above, this land was prepared for irrigation in September and October, and seeded to Hairy Peruvian alfalfa October 24, 1915, at the rate of 17 pounds per acre. The first cutting was made in the middle of March, and was mostly bur clover and volunteer wheat. The second cutting was excellent hay, though it contained a large proportion of volunteer wheat. The remaining four cuttings were all very excellent alfalfa. A total yield of 89 tons (measured) was obtained.

No trouble was encountered from Johnson grass in either the wheat or the alfalfa.

Table VI gives a brief summary of the costs of operations on the various fields, the sizes, and the returns therefrom. The third to the eighth fields inclusive were within the Johnson grass eradication experiment, and our main efforts were directed toward the control of this pest rather than financial profit.

TABLE VI. OPERATIONS, FIELDS, AND RESULTS OBTAINED ON THE SALT RIVER VALLEY FARM AT MESA, 1916

Type of farming	Size of fields	Cost per acre	Income per acre	Remarks
	acres	dollars	dollars	
Wheat	20	23.52	31.50	
Sudan	9	21.13	33.00	
Alfalfa	14	49.58	56.03	Cost per acre includes preparing ground and seeding
1 year dry fallow	40	17.58	None	Cost per acre includes 3 plowings, 2 being under very dry conditions
Winter grains and sheep pasture	20	32.62	27.14	On account of over-grazing value of sheep pasture just paid for irrigation expense
Intensive cultivation (cotton)	10	72.58	120.00	Johnson grass under control
Intensive cultivation (corn)	10	36.70	42.00	Johnson grass under control
1 year dry fallow and winter grains	20	14.45		
Continuous dry fallow	20	12.85		

It is the plan to continue the same methods of Johnson grass control on these same fields until the pest seems to be well in hand.

The effects of another season's work will undoubtedly shed much light on the situation, and it is inadvisable to draw too many conclusions at this date. However, certain points have been definitely noted and certain results have been obtained which are of interest. A discussion of these follows:

The matter seems to resolve itself into Johnson grass control rather than eradication. Irrigating water brings in enormous quantities of seed each summer, and plants from this source must be continually dealt with in the absence of a suitable method for screening out these seeds. It is as easy to control a seedling Johnson grass plant as any other weed, provided the work is done in time. As a usual thing the propagating rootstock starts to develop about the time the head is in the boot, or just before it appears above its protective sheath. Before this time a single cultivation destroys the plant. It follows, then, that after the old rootstocks are destroyed the key to the whole matter is to attack the seedlings before they have had time to develop rootstocks of their own.

The cost involved where the grass is kept down by intensive cultivation is very heavy, but the returns are often great enough to leave a margin of profit. By this method, the farmer can eventually get his place well rid of this pest without being denied the use of his land; and, by doing a large share of the work himself can accomplish the task without much outlay of actual cash. If this method is to be successful, he must have a cultivator that cuts every bit of plant material between the rows, and he must be able to do the work immediately when the necessity arises. When leaves are formed above the ground, this portion of the plant begins to feed the rootstock, and the only way to make any headway is to destroy the growth while the rootstock is feeding the above ground portion. If this is done the vigor of the rootstock is diminished during the best growing season at a surprisingly rapid rate.

Dry fallow is not as quick a method as intensive cultivation. A heavy rain may cause enough growth before the field can be entirely replowed to restore otherwise depleted rootstocks to normal vigor. Plowing in dry ground in hot weather is very expensive and slow work, and the farmer has a difficult situation to face when he has to bear this expense on land that is returning him no income.

Pasturing with sheep promises to be a favored method. The success of this depends on overgrazing. That is, enough sheep must be run on a field to graze every bit of the grass as close to the ground as possible. When the land has an abundance of water and the proper temperature to induce fast growing, the rootstocks can be very rapidly weakened. Sheep have the additional advantage of keeping ditches

clean. When a ditch is grazed thoroughly it is left in ideal shape, for the tramping and grazing of the sheep tend to smooth the sides and bed of the ditch, partially overcome the effects of gophers, and keep down brush and willow growth which make horse work difficult. Where a ditch is well grazed with sheep it is very rarely that any other work needs to be done to keep it in condition.

It seems highly probable that some headway can be gained by supplementing these Johnson grass control methods with fall plowing when practicable. When this is done, a great number of rootstocks will be brought to the surface and either killed or materially weakened by the frosts of winter.

PRESCOTT DRY FARM

The crops grown on the Prescott Dry Farm this year consisted of corn, beans, peas, grain sorghums, Sudan grass, saccharine sorghums, and small grains. The 50 acres in cultivation were divided into five fields as nearly equal as possible. Each field was then sub-divided into varying sized plats. The plats of any given field were devoted exclusively to one class of crops.

Fig. 4. Dwelling and farm buildings at the Prescott Dry Farm, July 30, 1916.

RAINFALL

Rainfall has direct bearing upon the success or failure of the farming operations on this farm. The season this year was very favorable

from a rainfall standpoint. Between five and six inches of rain fell during January, February, and March, and five inches fell during the growing season of July, August, and September. The rains were quite uniformly distributed over the growing months, this having much to do with the success of the crops on the Prescott Dry Farm this year.

CROPS

Corn: The following varieties of corn were planted from May 22 to June 12: Papago Sweet, Hickory King, Bloody Butcher, Reid's Yellow Dent, Silver's White Flint and Blue Squaw. All of the corn was cut for silage except a small patch of Hickory King and Bloody Butcher which was left for seed. Hickory King yielded the largest quantity of green silage per acre, while the White Flint and Blue Squaw were practically failures. Hickory King made 13,320 pounds of green silage per acre; Papago Sweet, 8,364; Bloody Butcher, 6,720; Reid's Yellow Dent, 4,500. The small Indian corns have appeared to better advantage during a less favorable season of rainfall and should be included in order to provide against complete loss of all corns when such seasons appear.

Beans: Tepary beans and Colorado Pinto beans were the two varieties tested this year. These were planted May 10, but later were nearly destroyed by rabbits. The teparies were completely destroyed and the Colorado Pintos yielded only 75 pounds of beans per acre.

Field peas: Six acres of Canada field peas were sown June 15, which was too late to take advantage of any winter moisture that was present earlier in the season. The majority of the peas did not germinate until July when the summer rains appeared. The season from this time on until frost was too short for maturing the peas, and the excellent growth of vines which they made during that time was turned under as a green manuring crop with no attempt made to harvest them.

Grain sorghums: The grain sorghums tested this year were Early Dwarf White milo, Standard Black Hulled White kafir, and shallu. These were planted June 1 on plats ranging from one-eighth to three-fourths acre in size. The entire crop of all the grain sorghums was harvested for silage except a small portion of the milo which was left for seed. An estimate of the yield of milo seed was 1260 pounds of grain in the head per acre. The yield of green forage was as follows:

Shallu	8062 pounds green silage per acre
Standard Black Hulled White kafir	5182 " " " " "
Early Dwarf White milo	4000 " " " " "

The grain sorghums are more drought resistant than corn and in a less favorable year would have compared more favorably with that crop. While shallu made the heaviest yield of forage it does not make the best silage and its growth should not be encouraged.

Saccharine sorghums: Club-top cane, Red-top cane, Early Amber cane, and Early Orange cane were tested in plats of more than one acre in size. These sorghums were all sown from May 10 to June 12. Club-top planted May 10 yielded 11,650 pounds of green silage per acre, Club-top planted May 31 yielded 11,456 pounds, Red-top planted June 9 yielded 5775 pounds, Early Orange planted June 9 yielded 8592 pounds, and Early Amber planted June 12 yielded 3686 pounds per acre. The Club-top out-yielded all of the other sorghums, and as a silage crop is very valuable as a supplement to corn.

Sudan grass: A little over 8 acres were planted to Sudan grass on May 10. One small plat was planted as late as June 5. This late planted plat was practically a complete failure due not so much to the date of planting as to the poor soil and the depth to which the seed was sown. All of the Sudan grass was planted in rows 40 inches apart with the exception of one-half acre which was set in 20-inch rows. The narrow rows yielded only 1000 pounds of dry hay per acre while the rest of the field, except the late planted plat mentioned above, yielded slightly over 1.5 tons of dry hay per acre. All of the Sudan was cut three times and furnished a considerable amount of green pasture between the time of the last cutting and the first frost in November.

Small grains: During the fall of 1915 several varieties of wheat and rye were planted, but all were either destroyed by winter killing or by rabbits, except one plat of rye. The rye had a very meager stand and was not worth harvesting. All the small grains were considered complete failures.

SILOS

During the year a 40-ton cement silo was constructed on the farm. This is the second silo to be built, the first one being a pit silo built the year before with a capacity of about 35 tons.

GENERAL CONCLUSIONS

Plowing should be done in this locality in the fall or early winter. Spring crops should be sown as early as late frost will permit in order to take advantage of the winter moisture that has been retained in the soil. Locally grown seed should be used on account of its acclimatization to local conditions.

SULPHUR SPRING VALLEY DRY FARM

The work on the Sulphur Spring Valley Dry Farm proved successful this year in demonstrating that feed can be produced in sufficient quantities to carry on a system of livestock farming. This success was due largely to the use of selected varieties of crops which have been proven adapted to this region, and to the copious rainfalls which were well distributed during the entire growing season.

WATER SUPPLY

The farm is operated so as to take advantage of any flood waters that may come upon it. It is also supplied with a small pumping plant which to a limited extent can be used to supplement dry farming operations.

Nine inches of rain fell on the place during the months of July, August, and September. The greater portion of this water fell during July and August in eight or ten showers, which thoroughly distributed it over these two growing months.

CROPS

Small grains: During the fall of 1915 sixteen varieties of wheat, and one each of oats, barley, spelt, emmer, vetch, and rye were planted on one-quarter acre plats. Nearly all of these varieties with the exception of vetch came through the winter with a rather imperfect stand and showed promise of making grain, but upon the advent of warm weather the lesser migratory locusts appeared and completely destroyed the crops.

Grain sorghums: The work with the grain sorghums—kafir, feterita, Dwarf and Standard milo—was largely a test to determine the proper date of planting. The best results from these tests were obtained with the March 17 planting of Dwarf Black Hulled White kafir. This crop produced 10,530 pounds of green silage per acre on a two-acre plat. Weights for the quantity of grain gave an estimate of 4001 pounds of grain in the head per acre. This was more than any of the other grain sorghums planted at any date. Feterita gave fairly good results with the July planting. This crop harvested 9504 pounds of green silage and an estimated yield of 2052 pounds of grain in the head per acre. The size of the feterita plat that gave these results was one-third of an acre. None of the plantings made on April 17 and May 18 produced a crop of sufficient amount to make those dates of planting practicable. With Dwarf kafir for March planting and feterita for

planting in July after the rains appear, the Sulphur Spring Valley farmer is amply provided with crops of this kind. The above crops of kafir and feterita were grown on some of the poorest soil on the farm. This particular portion of the farm is underlaid with clay and caliche at a depth of 18 to 24 inches and the water holding capacity of the soil is very low. In some seasons this portion of the farm receives copious floodings from an arroyo that comes down from the country above, but this year no such flood water was obtained.

Saccharine sorghums: Club-top cane and Black Amber cane were each planted on three dates: April 15, May 18, July 21, respectively. The Black Amber cane made a very poor showing in all of the plantings. The Club Top cane produced two tons of green silage per acre with the April 15 planting and 3.5 tons with the July 21 planting. July planting, however, was immature when harvested. The grain sorghums are superior to the canes for silage purposes, and, since the results indicate greater tonnage from the grain sorghums, there is little reason for the growing of the forage canes.

Corn: Six varieties of corn were tested. Plantings were made with each variety on three separate dates: April 16, May 15, and July 22, respectively. The April and May plantings resulted in very imperfect stands on account of insufficient moisture in the seed bed; while the July 22 planting did not afford ample time for complete maturity of the larger growing varieties, such as Mexican June. The Mexican June with each date of planting was superior to the other varieties tried, and appears to be a very excellent variety to grow under these dry farming conditions. The other varieties used in the trials were White Flint, Freeds, White Moqui, Mohave, and Papago Sweet. The April plantings of Mexican June yielded four tons of green silage per acre, and an estimated yield of 2490 pounds of grain in the ear per acre. The July planting of Mexican June was immature at the time of harvesting, but yielded 11,520 pounds of green silage per acre. The size of the corn plats varied from one-half to one acre. The smaller Indian corns did not equal the yields of the larger growing varieties this year, but in all probability in years of limited rainfall they would give returns when the larger growing corns would be a failure.

Canada field peas: Three acres of Canada field peas were sown February 29. The crop was a failure for two reasons,—heat and grasshoppers. The moisture conditions were good and the peas germinated well giving a perfect stand. When the peas reached a height of seven inches they stopped growing and stood at this size for several weeks until the grasshoppers eventually devoured the crop.

A winter legume is highly desirable in this region for soil building purposes, and more work should be done along the line of testing out either field peas or some other legume that could be used as a green manuring crop.

Tepary beans: Seven acres of Tepary beans were planted July 17. The beans were harvested October 5 and gave a yield of 752 pounds of recleaned beans per acre. After the beans were harvested

Fig. 5. Tepary beans on a windy day at the Sulphur Spring Valley Dry Farm. Yield, 752 pounds per acre.

the soil was left in excellent condition. All that was then necessary for the planting of small grains in this field was double discing and drilling.

Pink beans: Two acres of pink beans were planted on July 19, on land of the same character as the field of Tepary beans and received the same treatment in every respect as the above crop. Pink beans harvested October 22 yielded 208 pounds of recleaned beans per acre.

Cowpeas: Two varieties of cowpeas, Whippoorwill and Black-eyed, were planted July 19. The yields for the two varieties were 51 pounds of Whippoorwill peas per acre and 335 pounds of Black-eyed peas per acre. The Whippoorwill peas made much heavier growth of vine, but did not wholly mature its full crop of seeds. The Black-eyed pease were earlier and yielded a mature crop, but the vines were not so luxuriant. The Whippoorwill peas promised to be the best variety

for green manuring purposes. A crop of Whippoorwill peas could be planted to take advantage of summer rains and plowed under in the fall.

Sudan grass: Sudan grass was planted on three dates: April 15, May 18, and July 21, respectively. The April and May plantings gave a very imperfect stand which was further damaged by grasshoppers. The July planting was on very thin soil underlaid with caliche at a depth of about 12 inches. The yields in all the plantings were very unsatisfactory, less than a ton per acre being harvested from the April and July plantings, and only about 600 pounds per acre from the May planting.

Two cuttings were made from each plat. The results obtained from the work with Sudan grass should not be taken as evidence that this crop cannot be made to yield profitable returns on this dry farm. The performance of individual plantings more favorably located as to soil conditions and the appearance of portions of the plats where the early planted seed found sufficient moisture to germinate, indicates that if properly handled, Sudan will become a very valuable forage grass for this region.

CONCLUSIONS

The short season crops must be delayed until the coming of the summer rains in July. The dry farmer must farm with the moisture as the limiting factor; and to conserve that moisture and take advantage of it at the proper time is his main problem.

This year's results would indicate that Dwarf kafir, Mexican June corn and Sudan grass planted in March on fall plowed ground; feterita, Club-top cane, Tepary beans, cowpeas, and a second crop of June corn planted in July on a previously prepared seed bed moistened by the first rains of the summer, and small grains sown in October on the Tepary bean ground, would furnish ample feed for the livestock farmer, and at the same time give a crop of beans or wheat to be placed on the market for cash.

J. F. NICHOLSON,
Agronomist.
H. C. HEARD,
Assistant Agronomist.

BOTANY

Rainfall for the year ending June 30, 1916, was generally up to the average or somewhat above, for the State as a whole. This was true both as concerns the summer and the winter rainfall. As usual most of the summer precipitation took place during July and August. October and November were dry months and there was little growth on the ranges after the middle of October. The long dry fall was unusually favorable for the natural curing of the bunch grass growth, and also enabled stock to consume the heavy crop of mesquite beans before this could be damaged with moisture.

The winter rains were abnormally heavy during December and January and lighter than the average in February and March. As is well known, rainfall on the ranges before January 20 is of less value than that which comes later, and when heavy it may prove even detrimental. The heavy rainfall of the earlier winter months caused considerable erosion on the ranges and also serious floods in many of the river valleys and washes. Besides this, it damaged greatly the bunch grass feed on the ranges through leaching. And, finally, it came at a time when the temperatures were too low, even on the warmer desert ranges, for active winter annual growth. When the temperatures were more favorable, in February and March, the rainfall had dropped off greatly with the result that the growth of the late winter and spring forage was not as heavy as it would have been with a more timely distribution of the rainfall. The rainfall on the small range reserve, near Wilmot, Arizona, which is typical of southern Arizona ranges at the lower altitudes, may be cited as an example of this. The total precipitation for this area for the year ending June 30, 1916, was 13.95 inches, or about 2 inches above the average. Of this 5.65 inches fell during the summer period, July to October inclusive, and 8.17 inches in the winter season, December to April inclusive. Of the latter, 6.22 inches came during December and January, which left but 2 inches of moisture to mature the growth begun in the winter season. Naturally, this growth was shorter than it would otherwise have been.

ROOT-ROT DISEASE

During the year, Mr. Uphof and the writer devoted some time to the study of root-rot of alfalfa and fruit trees, both in the field and in the laboratory. This work led to the isolation of several different or-

ganisms or fungi, of which one was a species of *Fusarium*. This fungus was present in practically every culture made from roots of plants that had died from the disease known as root-rot, and it is believed to be one of the organisms causing this disease. This is apparently the same species of *Fusarium* that Dr. McCallum studied several years ago at this Station, in his work on root-rot. This fungus develops commonly in great quantity as a white filamentous growth on roots of plants that have recently died, when these are washed and placed in a moist, sterile chamber. It is quite easily obtained as a pure culture and grows readily in a large number of prepared media. With several trials Mr. Uphof did not succeed in inoculating healthy seedling alfalfa plants with cultures of this fungus. This inoculation work was done late in the season when the fungus was quite inactive, which may explain the failures. Unfortunately, it was necessary to discontinue this work last June after the departure of Mr. Uphof. As is well known, root-rot disease is widespread in our State and causes serious losses for the alfalfa grower, orchardist and gardener. Accordingly, this study should be completed at an early date so as to open the way for a possible economic control of the disease.

PUBLICATIONS

Bulletin No. 79, Cold Resistance in Spineless Cacti, was completed in July and is now in press. This work is an attempt to determine the factors which influence resistance to cold in spineless cacti and completes an Adams' fund project that was outlined three years ago. Spineless cacti have not proved very hardy in Arizona, which fact was noted in Bulletin 67 of this Station. This statement led to considerable inquiry and correspondence and was partly responsible for the present bulletin. For this work spineless cacti that were considered hardy, were secured from several sources and, with others that were known to be injured with a few degrees of frost, were planted in the introduction garden at the University Farm in the spring of 1913. The soil was loamy in character and the plants were given moderate care in the way of irrigation and cultivation.

The following varieties of platopuntias were among the more important of the ones planted: *Opuntia ficus indica* from Malta; *O. ficus indica* from Sicily; *Opuntia* sp. Burbank Special, regarded as very hardy; *O. fusicaulis,* a slender-jointed spineless pear; *O. castillae,* a spineless Mexican cactus growing in Tucson gardens; and *O. Ellisiana,* secured from Mr. B. R. Russell, San Saba, Texas.

Careful notes were kept on these plants concerning their rates of

growth, and relative resistance to summer and winter temperatures. It was observed in brief that *Opuntia castillae* and *O. Ellisiana* made less growth than the other species, but that they were hardier to winter temperatures. With these species growth usually ceased in October while the others often continued growth until severe frosts began in November. Naturally, the tender half-matured joints were killed with the first heavy frost.

In the summer of 1915, Mr. J. C. Th. Uphof, then assistant in botany in the department of biology, made laboratory studies, morphological and physiological, of joints of these plants in order to determine the factors of cold-resistance in cacti. Mr. Uphof found that the varieties of spineless cacti having relatively thick integuments may withstand a low temperature for a short time with little or no injury while those having thinner integuments would be injured. He also found that the collecting and freezing of water from the cells in the intercellular spaces during low temperatures is not in itself harmful to the plant. Also, that the protoplasm of the cell is not poisoned with the concentration of the cell-sap solution as a result of at least part of the water of the cell being withdrawn to the intercellular spaces and frozen. Mr. Uphof concluded that with normal cactus plants resistance to cold is inherent in the protoplasm, and for this reason some varieties can endure more frost than others.

Mr. Uphof's work checked quite closely with observations made by the writer relative to low temperatures in winter. He found that *Opuntia castillae* and *O. Ellisiana* were more resistant to cold than any of the other species and that *Opuntia Ellisiana* was considerably hardier than *O. castillae*. Mr. Uphof determined that *Opuntia castillae* would be injured with a temperature of 6.8 degrees F. During the winter of 1912-1913, it was severely frozen back on the University grounds with a temperature of 6 degrees F., and in December, 1916, it was injured at the University Farm with an estimated temperature of 9 degrees F.

The literary work of this bulletin was done by the writer, the reason for this being stated in the publication.

Timely Hint No. 117, Vines for Shade and Ornamental Planting, was written to meet a growing demand for information on this subject. This leaflet discusses briefly the value of vines for general planting and includes a list of the hardier species, both evergreen and deciduous, that are quite generally planted. Short descriptions of the varieties are given together with methods of cultivation. Vines are among our most ornamental plants. They are planted more in the Southwest than in other parts of the country, partly because of our

stronger sunlight and aridity, and also the quick shade which they supply. The following species were recommended for planting over the State: five-leaf ivy or Virginia creeper *(Parthenocissus vitacea* var. *macrophylla);* Japanese ivy *(Parthenocissus tricuspidata);* Japanese honeysuckle *(Lonicera japonica);* English ivy *(Hedera helix);* Arizona grape *(Vitis arizonica);* trumpet honeysuckle *(Lonicera sempervirens);* silk vine *(Periploca graeca);* Chinese wistaria *(Wistaria chiensis);* Chinese trumpet creeper *(Tecoma chiensis);* blue passion flower *(Passiflora caerulea);* Japanese virgin's bower *(Clematic paniculata);* western virgin's bower *(Clematis ligusticifolia;)* native hop vine *(Humulus lupulus* var. *neomexicana).*

Timely Hint No. 118, Crown Gall, deals with the well-known disease of orchard trees and suggests means for its control. Severe losses have resulted to Arizona orchardists from crown gall, and it may be looked for now in practically every agricultural community in the State. Recent studies have shown that in addition to deciduous fruit trees, hops, grapes and cane fruits, crown gall attacks roses, chrysanthemums, Paris daisies, walnuts, white poplars and similar shade trees besides field crops like sugar beets and occasionally alfalfa. Nurseries have played an important part, often unconsciously, in the spread of this disease. In the light of better information concerning the infectious nature of crown gall, and with stringent state inspection laws, there will be less danger than heretofore of introducing crown gall in one's orchard. However, the orchardist and farmer should exercise great care in purchasing nursery stock and insist that it be inspected properly by the state authorities.

STUDIES IN THE FLORA

This department is assisting the forest service in this State to identify the more important plants, both woody and forage species, that grow on our forest areas. It is also cooperating in a like manner with the Bureau of Biological Survey, Washington, D. C., relative to their work of mapping the life zones of Arizona. More than 200 plants were determined for the Coconino National Forest last summer and smaller lots for other of the forest areas. Thus far 180 species have been identified for the government biological survey work. Most of these plant specimens are deposited ultimately in the herbarium of the University for future reference. This work requires a considerable outlay of time, but it is invaluable since it enables the Botanist to become better acquainted with plants from widely separated localities in the State and their distribution. It also helps to make more nearly

complete the work on the flora. It has been the means of bringing to notice a number of species that heretofore were not known to occur in the State.

In addition to this, the writer practically completed during the year a study of the native *Pteridophytes* or fernworts, *Chenopodiaceae* or Goosefoot family which includes the saltbushes, and *Amaranthaceae* or Tumble-weed family. Studies were also made on the trees of Arizona which added several more species for the State, and work was begun on the grasses. Besides the above, two classes were taught each semester.

Six weeks of the past summer was spent in field work, principally about Prescott, Flagstaff, and the Grand Canyon. This trip was made by automobile with a camping outfit which made it possible to stop wherever interest demanded. Much valuable information was secured relative to grazing, carrying capacity of ranges, and poison weeds. The distribution and abundance of the more important plants was also noted. Quite complete plant collections were made at the Grand Canyon and Prescott. A careful study was also made of the shade and ornamental plants growing most successfully above altitudes of 5000 feet. The information on cultivated species is being included in a bulletin on the shade and ornamental plants of Arizona.

MISCELLANEOUS

The writer read a paper at the meeting of the American National Livestock Association, El Paso, Texas, last January, entitled The Practical Application of the Ferris Stock-raising Homestead Bill to Our Western Grazing Ranges. This was published in the Proceedings of the Nineteenth Annual Convention of the American National Livestock Association, 1916, pp. 116-120. This law was enacted recently, and the stockman may now take up a section of arid grazing land for a homestead.

J. J. THORNBER,
Botanist.

HORTICULTURE

The major part of the Assistant Horticulturist's time has been occupied in teaching. Extension work occupied twenty-two days' time. Experimental work with lettuce, beans, sweet potatoes, and egg plants occupied the remainder.

LETTUCE

The cantaloupe growers of Salt River Valley, in casting about for a crop to occupy their time and land during the winter months, first began to take serious interest in lettuce during the winter of 1914-15. The efforts of most of the growers this season were discouraging from a financial standpoint. The two most serious difficulties were in the matter of season and marketing. The writer, therefore, took up the task of aiding in the solution of these problems. The questions which arose were:

1. What methods of packing, loading, and refrigeration will insure the safe arrival of lettuce on the market?
2. What is the best variety for Salt River Valley?
3. What cultural methods would result in earlier maturity of the crop?

The Glendale growers, who are most vitally interested, solved or partially solved most of the shipping problems themselves during the season of 1915-16. They found that lettuce reached Eastern markets in excellent condition if the following precautions were observed:

1. Pack crates with a 3-inch bulge before the lid is put on.
2. Precool the packed lettuce in the cold storage room of the local creamery for 48 to 60 hours (or until a car is made up).
3. Load cars before daybreak.
4. Load the car only two-thirds deep.
5. Leave ventilating space between rows of crates in the car.

At the writer's suggestion Mr. S. B. Tatum, of Glendale, shipped a sample of lettuce to A. Steinfeld & Company, Tucson. The manager of the grocery department of this store suggested that the shipper line the crates with paper to prevent contamination in transit. Mr. Tatum acted upon this suggestion by lining the crates in a part of a car consigned to a commission merchant in Kansas City. Word came back from this merchant, "Line all crates hereafter. Lined crates bring 25 cents a crate more than unlined."

Work to decide the relative merits of different varieties was begun at the Yuma Date Orchard in the fall of 1915. The following varieties

were grown: New York or Los Angeles, Large Hanson, Denver Market, Iceberg, May King, Early Curled Simpson, Grand Rapids, White Paris Cos, Salamander, California Cream Butter, Big Boston, and White Summer Cabbage. Work at the Phoenix Farm the same year was designed to determine the value of manure in accelerating the maturity of the crop.

Following the first year's work an acre of ground at the Mesa Farm is now in variety and cultural experiments to determine (1) If any variety of the crisp type of lettuce is superior to the New York for market purposes; (2) If there are marked differences in different strains of New York; (3) What quantity of manure is desirable for the crop; (4) Can cotton seed meal be substituted for barnyard manure as a fertilizer; (5) Which method of culture is to be preferred—one single row on each ridge, double rows to the ridge, or flooding the crop. This work up to this time offers the following conclusions:

1. The crisp type of lettuce represented by New York, Iceberg, and many other varieties are to be preferred for Arizona conditions to the butter head type represented by Big Boston, Tennis Ball, and many other varieties.

2. Drilling the seed makes thinning easier than dropping the seed in hills.

3. Thinning can be done better and cheaper when the plants are very small.

4. Crowding in the row or delay in thinning delays maturity.

5. A heavy soil lacking enough organic matter to make it crumble can delay the maturity of the crop several weeks.

6. Applying rotted manure in large quantities (10 to 20 tons per acre), or plowing under a cover crop is necessary for a profitable crop in most soils.

7. It takes about 90 days of good growing weather to mature the crisp type of lettuce.

8. Poor seed, poor soil, cold weather, delayed thinning, and poor cultivation will increase this time.

ARIZONA CLIMATE AND BEAN ANTHRACNOSE

In the spring of 1916, Mr. A. N. Brown, editor of the *Fruit Belt*, Grand Rapids, Michigan, wrote that he had heard that anthracnose did not affect beans in this State. If this was true he thought Michigan growers would profit by using seed grown in Arizona. The writer was detailed to study the question.

Through the kindness of the W. A. Burpee Seed Company, of Philadelphia, samples of 36 varieties of beans were donated to the

Station, and were planted on the Sulphur Spring Valley dry farm near Cochise. Later Mr. Brown sent some diseased bean seed. The diseased seeds were planted in the middle of the variety block so that if the disease could develop in this climate it would have a good chance.

Professor J. G. Brown of the University made examinations of suspected material during the growing season and reported that he found an organism which looked like the anthracnose *(Colletotrichum Lindemuthianum)*, but no spores could be developed. After the crop was harvested Professor Brown was unable to obtain any cultures from the beans produced from the infected seed.

Of the varieties grown at Cochise all but the very late ones matured a fair crop of seed, showing that bean seed can be grown here if there is any superior quality in seed so grown.

STORAGE OF SWEET POTATOES

Since the sweet potato is an important garden crop in Arizona, the writer concluded that a study of methods of storage suited to Arizona conditions would be beneficial to the truck farmer. In one trial the potatoes were picked in the ordinary way, carried in sacks to the barn, and were spread in thin layers between straw. In the other trial only sound potatoes were chosen for storage. These were placed in crates in a room heated with an oil heater, and then piled between layers of straw as were the first lot. A report on the percent which keeps will be made in the spring.

KEEPING EGGPLANT

Although the eggplant is a vegetable of minor importance, the presence of summer vegetables on our tables in the winter season is generally welcome. The deterioration of the eggplant is due largely to evaporation from the skin. Noting this fact the writer October 25 dipped eight eggplants in melted paraffin, and hung them up by the stem. Three of the eight eggplants decayed from a brown rot. The other five were in good condition December 16 when one of the them was cooked in the ordinary way, the quality being as good as one direct from the vine. The other four are at this late, January 25, apparently in excellent condition. It may be that the rotting of the fruits can be prevented by disinfecting the surface before coating with paraffin. No rot developed which had not started within the first two weeks. The method appears to be a practicable one for home use.

S. B. Johnson,
Assistant Horticulturist.

PLANT BREEDING

Owing to the fact that a considerable part of the time of the head of the department was devoted to the additional duties which devolved upon him as acting Dean and Director of the College of Agriculture and Agricultural Experiment Station, and as a result of interruptions occasioned by other changes in the Staff, it was considered advisable to confine the work of the department for the year to the breeding of wheat, alfalfa, and the grain sorghums. The work with beans and sweet corn, and the transpiration studies with alfalfa were postponed.

WHEAT

The total acreage of experimental wheat plots at Yuma was 4.08 acres. The total yield of grain on this area was 7563.5 pounds of cleaned grain. The average yield per acre was 30.9 bushels. The alkali spots of the Dyer block reduced the yield to some extent, but in no place was the alkalinity strong enough to entirely prevent the plants from maturing seeds, except in two or three small places of negligible area. The growth on at least one-eighth acre was somewhat dwarfed on account of alkali. Some of the plots lodged badly while the plants were in bloom, and a high percentage of heads on these plots was completely sterile. Cold weather and a light frost came while some of the earlier strains were in bloom, and prevented them from setting a full crop of seed.

Owing to these abnormal conditions of weather during the growth of the crop, the yields of the different varieties in 1916 were very different from yields obtained in 1915. The highest yielding variety of 1916 was the Early Baart, making an average of 49.46 bushels per acre, while one plot of this variety yielded at the rate of 56.98 bushels per acre. This strain has been developed from a head selection made from a large field plot, and is proving to be very productive in the large test plots. The average yields for all the large test plots are given in Table IX.

TABLE IX. WHEAT VARIETIES AT YUMA, 1916

Name of variety	Yield per acre
	bushels
Early Baart	49.46
Sonora	39.08
White Algerian	29.00
Red Algerian	26.16

In addition to the large test plots, 65 pedigreed races were planted in increase plots. Each of these races was selected from the best head rows of the previous season's crop. The object of this experiment was to increase the seed from these excellent races, and to further test their yielding capacity when planted under practical field conditions. Although some of these races suffered severely from a late frost, and therefore made low yields, others outyielded the original races from which they were selected. A selection of Turkey Red wheat produced 51 bushels per acre, while the original stock from which this selection was made produced only 43.2 bushels in 1915. A similar gain in yield was obtained from nine other selections. The abnormal conditions of the spring weather, such as cold weather and late frosts, make it necessary to repeat this series next year.

The wheat hybridization project has been continued this year, and data on the third generation has just been completed. Reciprocal crosses of the following varieties have been studied: Early Baart x Macaroni, Sonora x Macaroni, Algerian Red x Macaroni.

The object of this project is to combine the hardiness, disease resistance, and high yielding qualities of the macaroni with the high milling quality of the bread wheats. A very exhaustive study of heredity in wheat has also been made. About twenty-five thousand hybrid wheat plants were grown at Yuma and harvested in the spring of 1916. Careful individual plant records were made of the following characters: Date of first head, height of plant, date of maturity, strength of straw, and rust resistance. The heads of each plant were harvested in a separate bag and the whole lot was shipped to Tucson where laboratory notes were taken on the following head characters: Number of heads, the dimensions of the largest head of each plant, length of awns, and color of chaff. A very extended study of sterility has been planned and carried forward during the past two years. This is one of the most difficult problems with which the plant breeder has to deal in producing high yielding strains.

ALFALFA

The alfalfa plots on Land 11 at Yuma were continued through the year 1916. Table X gives the total yields per acre from these plots.

Table X shows that the Peruvian alfalfa leads in yield, as it has done during the two previous years. It should be said that Plot 39b of the Peruvian is not thoroughly level. About one-third of this plot is too high to receive the same quantity of water as the other plots. This accounts for the low yield on this plot. A seed crop was also

taken from these plots. From the seed crop taken in 1915, these trial plots were transferred to the Mesa Farm, and the high yielding strains were planted in one-fourth acre plots.

TABLE X. YIELDS OF ALFALFA AT YUMA, 1916

No. of plot	Name of alfalfa	Total yield pounds per acre
39a	Hairy Peruvian	17772
11	Italian	16777
	Baltic (from Colorado)	15384
22	Algerian type (Bagdad)	15751
24	Algerian (Oued Rirh)	12121
39b	Hairy Peruvian	13352
27	Turkestan	12151
35	Siberian (Turkestan type)	13943
41	French (European type)	14476
39c	Hairy Peruvian	16657

Seeds were taken from all the pure lines of alfalfa growing at the Evergreen Nursery, anl these plots have been discontinued. Twenty-six plant selections were made from these plots and the seeds from these plants were planted in rows at the Mesa Farm last fall.

GRAIN SORGHUMS

As a preliminary test for securing good foundation stock for breeding work with the grain sorghums, sixty head selections of milo, feterita and kafir were planted at the Yuma Date Orchard in July. Approximately one hundred plants were grown from each selection, and the following notes were taken: Date planted, date up, date thinned to one plant in hill, date first head, date full head, date ripe, number of heads per plant, weight of heads from each selection cut not over one and one-half inches below base. These data will be used as a basis for further selection in breeding for higher yielding strains and more desirable types. A total area of one and one-eleventh acres was planted to these selections, and a total yield of 5758 pounds of head grain was obtained.

GEO. F FREEMAN,
Plant Breeder.
W. E. BRYAN,
Assistant Plant Breeder.

ANIMAL HUSBANDRY

Investigations in animal husbandry have been conducted along five different lines: (1) Sheep breeding experiments; (2) feeding Tepary beans to hogs; (3) supplmenting alfalfa hay for milk production; (4) ostrich investigations; and (5) study of the various systems of live-stock farming in Arizona.

SHEEP INVESTIGATIONS

The flock of sheep located in Salt River Valley has undergone considerable improvement this past year. All animals that were of inferior type or unsatisfactory in mutton, wool, or other qualities were discarded. The present flock has been materially decreased in numbers.

Wool study: The weights of wool of the various crosses of sheep have been studied during the past year. Instead of averaging the entire number of clips of wool of the different crosses as has been done in previous reports, the different clips of wool were compared with each other and with those of other crosses. This was necessary, for the Tunis-Native and the Hampshire-Tunis-Native crosses have many more old sheep than any other. It has been observed that the first clip is usually very light while the second and third clips are much heavier. Some of the crosses give their heaviest fleece at two years of age, while others give their heaviest clip at three yars. Still others have seemingly increased in weight of wool as they grew older. The sheep of some of the crosses have had three clips; and in comparing their wool only the first three clips were taken into consideration. Table XI shows the weights of wool according to clips of the various crosses for a period of six years.

The first clip averages the lightest of all, while the weight of wool gradually increases until the fourth and fifth clips which are slightly lower, but the sixth clip shows a marked increase over the others. It should be noted that before the sixth clip was taken most

TABLE XI. WEIGHT OF WOOL BY CLIPS AND CROSSES

Cross	1st clip		2nd clip		3rd clip		4th clip		5th clip		6th clip		Avg. first 3 clips
	No. of fleeces	Avg. wt.	No. of fleeces	Avg. wt.	No. of fleeces	Avg. wt.	No. of fleeces	Avg. wt.	No. of fleeces	Avg. wt.	No. of fleeces	Avg. wt.	
		lb		lb		lb		lb		lb		lb	lb
T/1	20	6.2	12	5.91	12	7.87	7	5.75	7	6.95	4	6.33	6.57
T N/2 2	72	5.11	72	7.84	65	7.49	65	7.87	56	7.39	38	8.40	6.80
T H N/2 4 4	17	4.63	11	6.63	7	4.80	3	6.00	1	7.50	..	...	5.29
T S N/2 4 4	26	5.00	15	6.59	5	6.20	2	5.12	..	...	..	...	5.77
T T N/2 4 4	10	4.76	10	6.90	8	6.91	5	6.53	1	6.00	..	...	6.14
S/1	5	5.81	6	6.54	6	7.31	4	6.25	1	4.00	..	...	6.60
S N/2 2	26	3.48	23	9.58	15	7.77	13	7.86	7	7.24	..	...	6.78
S T N/2 4 4	104	5.99	56	6.35	31	6.95	12	6.23	1	8.75	..	...	6.25
S H T N/2 4 8 8	7	4.13	8	5.61	4	5.29	..	...	..	...	..	...	5.00
H N/2 2	12	3.67	12	7.29	11	5.49	10	6.45	5	5.70	4	4.50	5.48
H T N/2 4 4	9	5.36	10	7.69	8	5.80	8	7.53	7	5.50	5	4.55	6.33
H T S N/2 4 8 8	13	5.50	5	5.93	2	6.00	..	...	..	...	..	...	5.66
H S T N/2 4 8 8	25	5.05	8	6.59	3	7.33	..	...	..	...	..	...	5.58
Average	..	5.34	..	6.82	..	6.89	..	6.80	..	6.55	..	6.93	...

of the inferior sheep were eliminated from the flock so that only the better ones remained. In comparing the average of the first three clips the Shropshire-Native cross averages the heaviest; the Tunis-Native comes second, the pure Shropshire sheep third, the pure Tunis fourth, and the Hampshire-Tunis-Native fifth. The three year average should be fairly reliable, because a large number of sheep were taken into consideration in each case. It is found that where there is a considerable proportion of Hampshire blood, the fleece runs light. The Tunis and Shropshire breeds cause a relatively higher weight of clip.

In order to get a fair comparison of the various clips of wool, those sheep having six clips were taken separately and the weights of their fleeces averaged. Only four crosses have had six clips including the pure bred Tunis, the Tunis-Native, Hampshire-Native, and Hampshire-Tunis-Native. Table XII gives the average weights in detail.

TABLE XII. WEIGHT OF CLIPS OF WOOL INCLUDING ONLY SHEEP HAVING SIX CLIPS

Cross	No. of sheep	1st clip	2nd clip	3rd clip	4th clip	5th clip	6th clip
		pounds	pounds	pounds	pounds	pounds	pounds
Tunis	2	4.50	5.60	4.60	4.35	5.10	5.35
T N / 2 2	24	5.83	6.73	9.35	6.92	7.52	6.72
H N / 2 2	3	1.92	6.92	3.92	4.50	5.17	3.55
H T N / 2 4 4	3	1.92	6.92	3.92	4.50	5.17	3.55
Average	..	5.03	6.83	8.18	6.46	6.97	6.10

The pure-bred Tunis sheared heaviest in their second clipping. The third and fourth clips were lighter, while their sixth clip was nearly as heavy as the second. The Tunis-Native cross sheared much heavier in the third year, but next highest in their fifth. This cross does not compare well with the other crosses in this regard. The Hampshire-Native and Hampshire-Tunis-Native crosses both gave a heavier clip at two years of age than at any other time. It is found in averaging the clips of these various crosses that the third clip is heaviest, the fifth clip next, while the second clip takes third place.

Twin inheritance study: It is highly important that a high degree of fecundity exists in a breed of sheep. It is readily seen that a flock throwing a large percentage of twins will increase in numbers much more rapidly than where single lambs are the rule. If there is any means by which the percentage of twin lambs can be increased it would be of value to sheep growers.

A study has been made of the Experiment Station ewes, to find whether any of the crosses being used were more productive of twins than others, and to find whether ewes that are twins are more likely to throw twin lambs than single ewes are. This study has not been finished, but the data in Table XIII is submitted to show the results of the investigation so far.

The Shropshire and Hampshire crosses as well as the pure-bred Shropshires seem productive of many twins. The Tunis breed and its crosses favor single lambs.

Both the single and twin ewes produced more single than twin

TABLE XIII. TWIN INHERITANCE STUDY

Cross	Single ewes			Twin ewes			Total	
	Ewes	Single lambs	Twin lambs	Ewes	Single lambs	Twin lambs	Single lambs	Twin lambs
Pure T.....	5	5	0	1	0	2	5	2
T N / 2 2	64	170	140	16	45	28	215	168
T S N / 2 4 4	8	13	0	6	7	6	20	6
T H N / 2 4 4	7	10	2	7	8	8	18	10
T H T N / 2 4 8 8	1	1	0	0	0	0	1	0
Pure S.....	2	4	4	1	0	4	4	8
S N / 2 2	13	22	16	15	20	30	42	46
S T N / 2 4 4	35	41	16	15	23	10	64	26
S H N / 2 4 4	1	1	0	0	0	0	1	0
S H T N / 2 4 8 8 ...	3	4	0	1	1	0	5	0
H N / 2 2	7	13	26	5	12	6	25	32
H T N / 2 4 4	6	11	14	0	0	0	11	14
H T S N / 2 4 8 8 ...	1	0	2	0	0	0	0	2
Pure Oxford	1	1	0	0	0	0	1	0
Oxf. crosses.	7	9	2	1	3	0	12	2
Other crosses	18	27	12	7	6	6	33	18
Total.....	179	332	234	75	125	100	457	334
Percent.....	...	58.65	41.35	..	55.55	44.45	57.77	42.23

lambs, but single ewes gave birth to a slightly larger percentage of single lambs than twin ewes did. The single ewes produced 58. 65 percent single lambs, while the twin ewes produced 55.55 percent single lambs. Twin ewes showed a slightly greater tendency toward twin production, having thrown 44.45 percent of twins as compared with 41.35 percent for the single ewes. Further study will be given to this question. The lambs dropped in the spring of 1916 have not been tabulated, but it is thought that they will not change the results greatly.

Monthly gains in lambs: During the past year the lambs have been weighed and a careful record made of the gains. Table XIV gives the average monthly gains of the lambs classified according to breeding.

TABLE XIV. GAINS ACCORDING TO BREEDING

Breeding	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
	lb	lb	lb	lb	lb	lb	lb	lb	lb	lb
Tunis.....	15.63	15.63	13.25	9.83	7.00	—0.20	2.00	6.70	7.20	—0.40
H T N.....	14.90	15.51	12.60	12.64	11.71	—1.18	11.50	6.46	2.81	1.75
T H N.....	17.80	16.33	15.38	13.09	11.16	1.50	4.34	7.34	2.67	1.50
Cross-bred...	15.50	14.00	13.23	14.00	10.27	—5.67	6.20	8.93	—1.21	—2.36
H S T N.....	14.75	15.94	13.90	11.26	9.38	—1.81	4.84	5.62	3.00	1.42
H T H N.....	15.50	16.83	16.67	12.83	11.25	—0.50	3.75	5.75	1.50	3.75
H T T N.....	15.50	13.50	12.00	5.00	13.00	—2.00	3.00	3.00	4.00	—5.00
T R.....	....	....	14.67	15.00	11.33	2.50	6.50	18.00	2.00	6.00
Average.....	15.65	15.39	13.96	11.57	10.57	—0.79	4.36	7.73	2.61	0.83

The greatest gains were made in February. Each following month the amount of gains gradually decreased until June, when the average for the flock was 10.57 pounds increase per month. The next month was especially warm and trying so that many of the lambs actually lost in weight. There were a few individuals that lost in either June or August, but not nearly as many as during July. Some slight differences are apparent between the rate of gains of the different crosses, but the average of each cross did not vary from the average of the flock. It was apparent that the lambs born in May lost relatively less than those born in other months, but these lambs seem to be retarded in their development and did not weigh as much in the fall as the early dropped lambs.

There were 57 lambs in the flock December 1, 1916. These lambs were divided into three groups according to weight. Table XV classifies them according to breeding and weight.

TABLE XV. CLASSIFICATION OF LAMBS BY BREEDING AND WEIGHT, DECEMBER 1, 1916

Breeding	Under 70 lb.		Between 70 and 89 lb.		Over 90 lb.		Total		Sexes	
	No.	Avg. wt.	No.	Avg. wt.	No.	Avg. wt.	No.	Avg. wt.	No. ewes	No. rams
		pounds		pounds		pounds		pounds		
T.....	3	53.7	2	78.5	0	0	5	63.6	3	2
H T N...	3	67.0	8	81.8	5	102	16	84.2	9	7
T H N...	4	60.3	1	80.0	1	94	6	69.2	2	4
Cross....	5	63.2	8	79.3	1	107	14	75.5	5	9
H S T N.	3	55.6	6	80.0	3	96	12	77.9	7	5
H T H N.	2	63.0	1	85.0	1	115	4	81.5	2	2
H T T N.	0	0	0	85.0	0	0	1	85.0	0	1
T R.....	0	0	0	0	1	0	1	100.0	0	1

Table XV shows that the Tunis lambs weighed less than any other breeding, averaging 63.6 pounds. The Hampshire-Tunis-Native lambs averaged 84.2 pounds, being the highest average where there were large

numbers in the lot. It so happens that there was only one lamb in two of the crosses and these were heavy. There was relatively a greater proportion of light than heavy lambs, and the heaviest lamb weighed 115 pounds. This was the Hampshire-Shropshire-Tunis-Native and lambs from this group rank second in general weight. There were some very light lambs among all of the crosses where large numbers were available. It is significant that the cross-bred lambs were lighter than the average in the flock and these did not seem to make more rapid gains than those from any other cross. The heaviest lamb in this group weighed 107 pounds, but there was a larger number of lambs in the group under 70 pounds from the cross-bred bucks than from any other, and the proportion of light lambs to heavy lambs was also greater than in any other breed, except in the pure-bred Tunis.

FEEDING TEPARY BEANS TO HOGS

Little information is available regarding the feeding qualities of Tepary beans, although they are sometimes fed to livestock in the Southwest. On this account a feeding experiment was planned to serve as a preliminary study of the feeding qualities of Tepary beans. Beans were fed to hogs of different sizes to ascertain as many details as possible regarding how best to feed them as well as the feeding qualities. Two distinct trials were made: The first was to feed a young pig on ground Tepary beans alone, anl the second to feed rolled barley in comparison with a mixture of rolled barley and Tepary beans made up in equal parts by weight. In estimating the cost of gains, rolled barley was valued at 1½ cents per pound and Tepary beans at 3 cents per pound.

Feeding a young pig on cracked Tepary beans alone: A Duroc-Jersey pig ten weeks old was placed in a pen 12 by 20 feet and given all the water and cracked Tepary beans it would consume. The pig weighed 30 pounds at the beginning of the period, but it rapidly lost in weight. The animal refused to eat the cracked Tepary beans and weighed 21¾ pounds or a loss of 8¼ pounds at the end of 35 days. It was apparent the pig would die and the experiment was discontinued.

No doubt the unpalatable nature of the food rather than its nutritive qualities was the cause for the small consumption, for pigs fed cooked Tepary beans consumed them in reasonable quantities. After the pig was placed in an alfalfa lot, and given rolled barley and skimmed milk, it soon made rapid gains and developed into a healthy animal, but slightly smaller than its litter mates.

Feeding rolled barley vs. Tepary beans and rolled barley to grown shotes: Four Poland-China shotes from the same litter were divided

into two lots averaging 147 pounds. These animals were uniform and received similar treatment from birth. Over a period of 64½ days the pigs were fed in a dry lot. Lot 1 received rolled barley and water, while Lot 2 received rolled barley, Tepary beans and water, the grain being mixed in equal proportions by weight. Rolled barley is not considered an especially palatable food for hogs, and it is unbalanced, being deficient in protein. On the other hand the beans are rich in protein, and according to its composition should be well suited for balancing the rolled barley. It is thus shown that Lot 1 was fed a more or less unbalanced ration while Lot 2 was fed a better balanced ration.

The pigs were fed twice a day throughout the experiment. The amount given Lot 1 was regulated according to the consumption of the feed by the pigs receiving the mixture in Lot 2. Each lot was started by giving it five pounds of the feed daily or approximately 1.66 pounds per hundred pounds live weight. At the outset of the experiment the pigs in Lot 2 did not take kindly to the Tepary bean mixture, and did not make satisfactory gains. They carefully picked out the rolled barley from the feed, and did not consume much of it. The next endeavor to induce the pigs to consume the Tepary bean mixture was by grinding the rolled barley and the cracked beans finely and mixing them thoroughly. This did not have the desired effect as the pigs refused to eat the mixture and 12½ pounds were weighed back. The feed was made into a wet mash, but this did not increase its palatability. The pigs in Lot 2 were apparently hungry and losing weight; they became restless and rooted more in the ground than those in the other lot. Fifteen days after beginning the experiment the beans were cooked and mixed with rolled barley and the pigs ate them greedily. After this the beans were eaten with relish, and it did not make much difference whether they were ground or whole if cooked. It was found that by soaking the beans overnight and cooking them about 30 minutes they were improved in palatability.

	Lot 1	Lot 2
No. of days in test	64½	64½
Total feed consumed	365 pounds	351.5 pounds
Feed consumed daily per animal	2.81 pounds	2.80 pounds
Total cost of feed	$ 5.48	$ 7.91
Total gains	64 pounds	42 pounds
Average daily gain	.99 pounds	.65 pounds
Food required per 100 lb. of gain	570 pounds	837 pounds
Cost to produce 100 lb. of gain	$ 8.56	$18.83

The pigs in the two lots were given the same amount of feed, namely, 365 pounds, but 12½ pounds were weighed back from Lot 2, before the beans were cooked. After this time the pigs consumed the same amount of feed which was gradually increased until each lot con-

sumed 8 pounds of feed at the end of the experiment. The following is a summary of the results of this test:

The hogs consumed about the same amount of food daily, but the cost of the feed was much higher in Lot 2 than in Lot 1, owing to the high market value of the Tepary beans. When rolled barley was fed, 570 pounds were required to produce 100 pounds of gain, while 837 pounds of the mixture of Tepary beans and rolled barley were required to produce this amount of gain. No doubt the inferior start which Lot 2 had in the beginning of the experiment militated against either large or economical gains. However, it is significant to note that the gains were greater from the lot receiving rolled barley than from the same amount of the mixed food. It is further interesting to note that the hogs receiving the mixed food or balanced ration only gained 42 pounds, while the others gained 64 pounds. This is an increase of 50 percent in the gains from the same amount of food. The cost of producing 100 pounds of gain was $8.56 for Lot 1 and $18.83 for Lot 2. Certainly one can not hope to make economical gains from feeding Tepary beans valued at 3 cents per pound to hogs.

EFFECT OF ROLLED BARLEY ON ALFALFA-BEET PULP RATION FOR MILK PRODUCTION

For the past few years the University has been feeding dried beet pulp and alfalfa hay to the dairy herd. Believing that it would be more economical to replace a part of the beet pulp with some grain, a test was run during the spring of 1916 to determine whether it would pay to feed equal parts of rolled barley and beet pulp rather than beet pulp alone as the concentrate part of the ration. Beet pulp is cheaper in price than rolled barley, it costing only $1.35 per cwt., while the latter retails at $1.70 per cwt. It has given splendid results as a feed for dairy cattle, and it is usually cheap in price compared with other feeds.

Beet pulp and rolled barley are about the same in percentage of digestible nutrients, the barley being a little higher in digestible crude protein and fat, but lower in carbohydrates. Since alfalfa is low in carbohydrates but relatively high in protein, it furnishes the greater part of the protein required in the ration. Where figured at $14.00 per ton, alfalfa hay furnishes nutrients most cheaply, the beet pulp ranking next and the barley last.

To get a fair test on the rations, ten of the cows were divided into two lots, balancing the lots as nearly as possible according to breed,

period of lactation, and amount of milk given. Owing to the limited number of cows, it was impossible to balance the lots perfectly, but they were even enough to compare favorably. One lot was fed molasses-dried-beet pulp as the sole concentrate, while the other lot was fed a mixture of equal parts of rolled barley and molasses-dried-beet pulp, both lots being fed at the rate of about one pound of the concentrate to four pounds of milk produced. The alfalfa was fed to both lots alike, and they were given what they would clean up well. The rations were alternated, so that the lot receiving rolled barley during one period did not receive it during the following period. The actual test covered a period of 68 days.

In Table XVI the data are arranged according to feeds fed, so that the results of each ration can be readily compared.

TABLE XVI. ALFALFA, BEET PULP, ROLLED BARLEY *vs.* ALFALFA, BEET PULP FOR MILK PRODUCTION

	Milk produced	Cost of ration	Feed cost per 100 lb. milk	Feed cost per gal. milk	Value of milk at 25 cts. per gal.	Profit over cost of feed
	pounds	dollars	dollars	cents	dollars	dollars
Lot fed alfalfa, beet pulp and rolled barley.....	7316.2	91.75	1.25	10.7	212.68	120.93
Lot fed alfalfa and beet pulp	6993.4	87.00	1.24	10.7	203.29	116.29
Difference caused by barley	322.8	4.75	.01	.0	9.39	4.64

A greater amount of milk was produced when barley was substituted for half the beet pulp. Barley being higher in price than sugar beet pulp, increased the cost of the ration, but enough more milk was produced when it was fed to make the feed cost per 100 pounds or per gallon of milk about the same as where beet pulp was the only concentrate fed.

Valuing the milk at 25 cents per gallon, that produced by the lot fed barley was worth $212.68 as compared with $203.29 when no barley was fed. Barley caused an increase of $4.75 in the cost of the ration, but it caused an increase of $9.39 in the value of milk produced, making $4.64 more profit over cost of feed than where beet pulp was the only concentrate fed.

The cows relished the feed more where barley was mixed with the beet pulp, and they cleaned it up better. Some of the cows would refuse to eat the beet pulp alone after becoming accustomed to having rolled barley mixed with it. The cows held up a little better in weight during the time that barley was substituted for part of the beet pulp.

OSTRICH INVESTIGATIONS

During the past year ostriches have been fed an average of three pounds of alfalfa hay, one pound dried beet pulp, and one pound of grain daily. The grain ration has consisted chiefly of whole wheat, but milo maize and barley have also been fed. At the present time there are fourteen old ostriches, two yearlings, and six spring chicks. The heavy snow storm of the winter caused all but two of the strongest yearlings to die. It thus seems that young ostriches can not endure much cold. This snow storm did not seem to injure the older birds. A careful record was kept of the eggs as they were laid. Table XVII gives the egg record for each hen arranged according to breed for the years 1915-1916.

TABLE XVII. EGG RECORD FOR EACH HEN ARRANGED ACCORDING TO BREEDING FOR THE YEARS 1915 AND 1916

Breed	Hen	Eggs laid		Average weight of eggs		Total weight of fresh eggs
		1915	1916	1915	1916	1916
				grams	grams	grams
South African	1410	23	30	1279.6	1406.75	42,202
South African	2071	11	25	1489.3	1483.50	37,088
South African	2105	34	34	1496.5	1566.80	53,274
South African	2136	7	26	1510.7	1571.40	40,858
Average...		20	28.75	1440.3	1507.11	43,355.6
Nubian	No No.	12	16	1473.0	1585.0	25,360
Nubian	2170	41	35	1704.9	1608.9	56,313
Average...		26.5	25.5	1588.95	1596.95	40,836.5
Crossbred ...	2305	21	31	1485.7	1542.4	47,816
Crossbred ...	2180	41	33	1612.7	1600.8	52,827
Crossbred ...	2292	5	34	1761.6	1801.0	61,234
Average...		37.33	32.67	1620.0	1648.0	53,959
Average for flock		22.22	29.33	1536.91	1579.43	46,330.3

Number of eggs laid by each hen: The different hens laid from 16 to 35 eggs each. With the exception of the old hen, no number, the range was 25 to 35 eggs for the individual hens. The average number of eggs laid was 7.11 greater than the previous year, and there was much less variation in the number laid by the hens. The average number of eggs laid by the flock was 29.33. The three cross-bred hens laid an average of 32.67 eggs per bird, while the South African gave the next highest average, 28.75, and the Nubian 25.5 eggs per bird. It so happened that the hen that laid the fewest eggs was a Nubian, and also the one that laid the greatest number of eggs was from this breed.

Since there was a greater range in the birds of the same breed than between the average of the different breeds, no definite conclusion is justified with regard to the breed of the birds as affecting the number of eggs that they lay.

Average weight of eggs laid: There is remarkable similarity between the general appearance and weight of eggs laid by the same hen over the two years. The ranking of the birds was very similar to that of the previous year. Three of the birds laid eggs with a lighter average weight while six of them gave eggs that averaged from 27.15 grams to 112 grams heavier than that of 1915. Table XVIII indicates the increase or decrease in the average weight of eggs laid by the different hens in 1916 as compared with 1915.

TABLE XVIII. COMPARISON OF THE AVERAGE WEIGHT OF EGGS LAID BY EACH HEN FOR TWO YEARS

Breed	Hen	Increase 1916	Decrease 1916
		grams	grams
South African.....	1410	127.15	....
South African.....	2071	.....	5.80
South African.....	2105	70.30	....
South African.....	2136	60.70	....
South African.....	Average	63.09	....
Nubian	No No.	112.00	....
Nubian	2170	.....	96.00
Nubian	Average	8.00	....
Cross-bred	2305	56.70	....
Cross-bred	2180	.....	11.90
Cross-bred	2292	39.40	....
Cross-bred	Average	28.07	....
Average of flock		42.52	....

The above table indicates that there were slight variations between the average weight of eggs laid by the different hens over the two years, but there is a remarkable similarity between the two years. The average of the entire flock was 42.52 grams heavier in 1916 than in 1915. This is a very small increase for it is less than two ounces difference between eggs that weigh approximately 3½ pounds. In other words the average weight of all the eggs laid in 1916 was 2.8 percent heavier than that of the previous year. As some of these birds were immature, it is thought that the increase in the average size of the egg was due to natural development rather than to the feed they consumed.

Again, hen No. 1410 laid the smallest average weight of eggs and No. 2292, the heaviest. The same relative position was occupied also by the hens that laid the second, third, and fourth heaviest average weight of eggs each year. Hen No No. laid eggs that were large the early part of 1915, but she received an injury about the middle of

the laying season, after which the eggs laid by her were much smaller. In 1916 the eggs from this hen were more comparable in size and appearance with those that were laid the year before the injury. This partly accounts for the greater increase in the average weight of eggs laid by this hen in 1916 over that laid by any other hen. Table XIX gives the ranking of the birds according to the average weight of eggs laid by each hen during the two years.

TABLE XIX. HENS ARRANGED ACCORDING TO AVERAGE WEIGHT OF EGGS FOR TWO YEARS

Ranking 1915	Hen	Average weight of egg, 1915	Ranking 1916	Hen	Average weight of egg, 1916
		grams			grams
1	1410	1279.6	1	1410	1406.75
2	No No.	1473.0	2	2071	1483.5
3	2305	1485.7	3	2305	1542.4
4	2071	1489.3	4	2105	1566.8
5	2105	1496.5	5	2136	1571.4
6	2136	1510.7	6	No No.	1585.0
7	2180	1612.7	7	2180	1600.8
8	2170	1704.9	8	2170	1608.9
9	2292	1761.6	9	2292	1801.0

The weight of eggs laid by each hen, 1916: There was a great range in the total weight of ggs laid by each hen. Thus hen No No. gave 25,360 grams of eggs, while hen 2292 laid 61,234 grams. This is a difference of 142 percent between the eggs laid by the hen that gave the lightest weight of eggs and the one that laid the greatest weight. Between these extremes the hens range close to the average, which was 46,330.3 grams or 102.3 pounds. Table XX ranks the different hens according to the total weight of eggs laid.

TABLE XX. HENS ARRANGED ACCORDING TO TOTAL WEIGHT OF EGGS, 1916

Ranking	Hen	Total weight of eggs, 1916
		grams
1	No No.	25360
2	2071	37088
3	2136	40858
4	1410	42202
5	2305	47816
6	2180	52827
7	2105	53274
8	2170	56313
9	2292	61234
Average of flock		46330.3 (102.3 pounds)

Effect of breed: Again, it was noted that the South African eggs are distinctly smaller than the Nubian or cross-bred eggs. They are more deeply pitted on the surface and have not the gloss shown in the Nubian or cross-bred eggs. With the exception of one bird, 2305,

which laid an egg that was lighter than the other cross-breds, there is a striking uniformity in the weight of the eggs laid by the birds of different breeding. Thus the South African hens averaged 1507.11 grams, while the Nubian averaged 1596.95 grams, and the cross-bred 1648.0 grams. There was not one of the South African hens in 1916 that laid eggs as large as any of the Nubians or cross-breds with the exception of 2305, as previously mentioned. The South African yielded eggs that averaged 89.85 grams less than the Nubian and 140.89 grams less than the cross-breds. These figures are similar in many respects to those secured the previous year.

INSTRUCTION AND EXECUTIVE WORK

Along with investigations summarized above time was given to teaching students and conferring with practical farmers who came for personal advice. The correspondence has been unusually heavy and considerable executive work has been required in the department. A reinforced concrete silo has been installed at the University Farm, and also a silo filling outfit. Other facilities for taking care of the livestock at the farm have been secured.

There has been little change in the number and kind of animals maintained on the University Farm. During the past year 11 cows completed lactation period averaging for the herd 55 days dry before calving, 332 days in milk, and yields of 8231 pounds of milk, and 327 pounds of butter fat. The registered Hereford cows all dropped calves within the year, and most of these have been sold at ruling prices. During the year the University purchased four registered Hampshire ewes, and these are also retained for class room work, along with the Shropshire and Tunis breeds.

Four breeds of chickens, namely: Single Comb White Leghorns, Single Comb Rhode Island Reds, White Plymouth Rocks, and Black Langshans are being maintained in the poultry plant. These are used chiefly for class room purposes.

A special effort is being made to develop uniform flocks and herds suitable for experimental purposes in the future. The livestock maintained is entirely inadequate for these purposes, but it is hoped that the numbers may be increased, and the quality improved so that the animals will be especially suitable for investigation and class room purposes.

R. H. WILLIAMS,
Animal Husbandman.
W. S. CUNNINGHAM,
Assistant Animal Husbandman.

ENTOMOLOGY

An extensive series of experiments in the control of the alfalfa seed chalcis fly was planned in the spring of 1915, and arrangements were made with eleven alfalfa seed growers near Buckeye and Chandler for testing out the trap border control method mentioned in the last report. The heavy rainfall in the late winter resulted in such variability in the growth of alfalfa that in several instances the growers abandoned their plans for producing a seed crop in the fields in which the tests were arranged for, and in other cases the growers failed to follow the plan agreed upon owing to a misunderstanding of their directions to workmen. In all other cases the period of eight or ten days allowed between the cutting of the borders and the main part of the field resulted in too slight differences in the setting of seed pods. The outcome was disappointing in view of the time and efforts made to arrange for the cooperative experiments on a large scale. It is believed that in further work along this line fourteen to fifteen days should be allowed for the differences between the trap borders and strips and the main part of the field. Continuous oversight of such experiments, which it has not been possible to give so far, will be necessary before they can be conducted satisfactorily.

Work against the harvester ants in the ten-acre field near Phoenix has continued. Conditions in the field were more unfavorable than would occur in the average field. Owing to lack of care during 1915 a heavy crop of foxtail grew in the field in the spring of 1916. This was cut, and on May 12, when the season's work against the ants began, it was lying on the field so as to make it difficult to find the nests. During the season a total of 74 nests were found and treated, including many weak colonies which appeared to consist of only a few individuals in each case. The nature of the nests is indicated by the fact that an average of only 1.3 ounces of London Purple were needed for each nest during the season, whereas two seasons ago in the same field the poison required for the 168 nests averaged 2.7 ounces each. The labor and expense for the treatment has been increased disproportionately to the possible injury from the ants owing to the splitting up of the larger nests. Eliminating labor which should be charged to the experimental end of the work and putting all expenses on a basis of practical farm work the cost for the year 1916 averaged about 64 cents

an acre as compared with 40 cents in 1915 and $1.19 in 1914. This experiment will be continued for two more seasons, making five in all.

An outbreak of one of the false chinch bugs *(Nysius minutus* Uhl.)* in the spring of 1916 in the Salt River Valley called for some attention from the experimental standpoint. The most important crops attacked were Irish potatoes and flax. The principal source of the insects seems to have been the common pig weed, *Chenopodium album.* On weeds the insects may be destroyed by means of blast torches or strong sprays of kerosene emulsion. On vegetable crops nicotine sulfate—whale oil soap solution was recommended. Experimental work with these insects was limited to attempts to control them on experimental plots of flax at the Experiment Station Farm near Phoenix.

On May 15 the flax plants were literally swarming with the bugs, mostly in the adult stages. The seed was the special object of attack, the entire seed crop being seriously threatened. The flax was growing in rows and collecting the insects by mechanical means was obviously the most practical method of protecting the crop. A special galvanized iron collector was devised to be used with a film of kerosene on water in the collecting pan as in ordinary hopperdozers, and this proved satisfactory for work on small plots. For collecting these insects on large acreages of flax the same principle has been incorporated in plans drawn up for a simple device on wheels which can be pushed at a walking pace along the row. Flax seed seems to be a promising crop for southern Arizona and these bugs will have to be contended with from time to time if this industry is developed. Their control by mechanical means in flax fields appears to be an easy matter. The collecting device will be perfected and given a practical demonstration when the false chinch bugs appear again in injurious numbers.

A. W. Morrill,
Consulting Entomologist.

*Determined by the late O. Heidemann of the U. S. Bureau of Entomology. Closely related if not a subspecies of the common false chinch bug, *Nysius ericae* Schill (*N. angustatus* Uhl.)

CHEMISTRY

The chemical laboratories of the Agricultural Experiment Station have been moved during the year into their new and permanent quarters in the Agriculture Building. The allotment for the equipment of these laboratories has been used for the substantial and permanent installation of only the most essential furniture, rather than in attempting to complete the laboratories. Sufficient equipment is now in place to continue the research and other activities of the laboratory. Further improvement, however, is needed to meet the increasing demands upon the department. The usual service has been rendered the public in the analysis of irrigating water and the examinations of soils for alkali. A few soil analyses have been made in urgent cases. The research work of the department has been varied and several important projects are being developed. The study of alkali has continued and accurate maps have been drawn showing the stand of successive crops on a piece of black alkaline land at the University Farm. This tract has been divided into strips by the borders usual on irrigated land, and the various strips have received treatment per acre as follows:

Land 30, 10 tons barnyard manure; Land 31, 20 tons barnyard manure; Land 32, 20 tons barnyard manure and 10 tons gypsum; Land 33, 10 tons gypsum; Land 34, no treatment; Land 35, 400 pounds acid phosphate and 20 tons barnyard manure; Land 36, 500 pounds acid phosphate; Land 37, 400 pounds quicklime; and Land 38 (new border), 500 pounds nitrate of soda in three applications, only one of which was made.

Parallel with the field operations laboratory investigations are being made. The alkali studies have now been organized as an Adams Fund project. The annual analysis of the Salton Sea water in cooperation with the Carnegie Desert Laboratory has been made. Following suggestions afforded by the study of the concentration of the Salton water, we have made partial investigations of certain possibilities regarding the mode of formation of caliche which seem to warrant further work. Monthly samples from the Tempe drainage ditch are being analyzed for the systematic study of the changes in the composition of the drainage water from a typical drained reclamation area. It is desired to extend this investigation to the amelioration of alkali in the soil at a few selected localities in the district. The effect of non-essential elements, especially boron and iodine, in stimulating plant growth has been carried on in the department by a graduate student.

SALTON SEA WATER

The tenth annual sample of the water of Salton Sea was taken June 10, 1916, over deep water off Salton. The results of the analysis are given in Table XXI.

TABLE XXI. COMPOSITION OF SALTON SEA WATER, JUNE 10, 1916

	Parts per 100,000
Total solids (at 110°C.)	1647.2
Water of oclusion and hydration	47.5
Sodium	528.9
Potassium	5.71
Calcium	29.85
Magnesium	27.17
Aluminum	.034
Iron	.060
Carbonic, CO_2 (total)	11.40
Bicarbonic, HCO_3 (volumetric)	16.10
Silicic, SiO_4	1.21
Phosphoric, PO_4	doubtful trace
Boric acid	trace
Oxygen consumed	.170
Nitric	none
Nitrous	trace

From June 8, 1915, till June 10, 1916, the total solids in the Salton water have increased from 1377.4 parts per 100,000 to 1647.2 parts per 100,000, which is equivalent to a concentration of 19.6 percent. This is the greatest annual concentration noted with one exception, the concentration from June 8, 1909, till May 22, 1910, having been 21 percent. Aside from the concentration of the solids collectively, there is little requiring discussion at this place. Mention, however, should be made of phosphoric acid. In the early annual analyses of the series weighable amounts of yellow precipitate were obtained. For several years the phosphoric acid test remained positive by scratching the sides of the beaker with a stirring rod, but at this time no unmistakable reaction can be obtained from three liters of water. Phosphoric acid, therefore, has been reported as a doubtful trace.

Early in this series of analyses of the Salton water it became evident that calcium and carbonic acid were being lost. How this loss took place was not evident. Algae and bacteria were known to deposit lime, and J. C. Jones showed the ancient deposits of travertime about the Salton Sea to have been formed in this way. Later the writer called attention to the fact that potassium, although present in the water in very small amounts, was following the same course as the calcium. Undoubtedly phosphoric acid and possibly nitrogen must be added to the same list.

This observation on the behavior of phosphoric acid has important bearing on the theory of soil fertility. Probably aside from physical and chemical processes, plant foods are fixed from the soil water and conserved by lower organisms in deposits other than their own temporary remains.

CALICHE

Large areas of mesa soil in the Southwest are underlaid at various depths by deposits of lime-cemented soil, sand, and gravel commonly called *caliche,* but recently named desert limestone by geologists. While these areas, because of the caliche, are less valuable for agricultural purposes, the analyses published in the Twenty-fourth Annual Report of this Station, page 567, show caliche itself to be supplied with plant food as richly at least as the soils with which it occurs. Because of its dense, hard character caliche takes water badly and plant roots cannot penetrate it. Nevertheless, where covered with a fair amount of soil, these desert limestone areas may become important in the production of special crops such as cactus, agave, guayule, and desert olives. It has generally been held that caliche resulted from some form of evaporation. The usually accepted theories are given in detail in Guild's *Mineralogy of Arizona,* page 48. Reasoning from observations made in connection with the study of the Salton Sea the writer was led to suspect the organic origin of these limestone deposits. Consequently, field and laboratory studies have been begun. In the field the lower courses of caliche are dense, while toward the top of the deposit calcareous caps with occasional interlying layers of uncemented soil are more frequent. Occasionally, however, caps are found beneath strata of dense caliche a foot or more in thickness. The strongest evidence of organic origin of caliche is found in these caps. The topography of the capped surface is very irregular and successive overlying caps often approach within two or three inches at one place, while ten feet away they may be separated by a foot or eighteen inches of cemented gravel. The caps in passing over boulders take the curvature of the boulder, and even may be found overhanging. Instances occur of erosion of the massive caliche and a subsequent deposition of a cap over the nearly perpendicular eroded surface. It would be difficult to explain these features by evaporation or simple sedimentation. Generally the caps occur on massive beds of cemented gravel, but frequently seams of gravelly loam an inch and even more in thickness may be found overlying one cap with a second thin cap overlying the loam. The lower face of the cap in contact with the loam is an exact cast of

the top of the loam layer and non-adherent to it, but its upper surface is quite regular and smooth. Pebbles embedded in the cap are frequent, and the laminae formed after the pebbles became embedded take the contour of the pebbles. When a broken cap is examined in a proper light, it is seen to be laminated and the laminae show various shades of color, from nearly white to chocolate according to the foreign material that became trapped in the lime deposit as it was forming. Thus the caps could have been formed only at the surface and not by any sort of subsurface evaporation. Caliche-like incrustations of considerable thickness occur over basalt rocks on the slopes of buttes adjacent to Tucson. Fossils are absent in caliche with the exception of diatoms, which the writer has found only in one specimen. From its mode of occurrence caliche appears to have been formed by lime-secreting organisms either in water or on surfaces that were frequently wetted with limy waters. During intervals of comparative quiet when little debris was being introduced and there was little interruption to the growth of these organisms the smooth caps may have been laid down.

A few observations that may be corroborated by anyone during the summer months render this theory more plausible. Leaky hydrants supplied with the hard Tucson city water rapidly become covered with lime-secreting algae and deposits of appreciable thickness are formed. These deposits cannot be due to evaporation. On the contrary flowing hydrants on the University grounds, supplied with a less hard, slightly black alkaline water, form only light lime deposits. On hot summer days with intense insolation caliche roads under lawn sprinklers become green with algae (probably lime-secreting species) in two or three hours. If these processes were continuous and extraneous matter introduced, undoubtedly caliche-like deposits would be formed.

The chemical evidence of the organic formation of caliche has been less completely worked out. It appears, however, that the percentage of readily soluble potassium and the potassium-sodium ratio is quite high in caliche. A few comparative determinations of phosphoric acid on caliche and on the interlying and overlying loams show the phosphorous content of caliche much higher than that of the associated soils. If caliche were merely lime-cemented soil we would expect the opposite relation to exist, phosphates being moved but slowly by ground waters. Further analytical work will probably corroborate these observations, and show the similarity of caliche to travertines of known organic origin.

PLANT STIMULATION WITH NON-ESSENTIAL ELEMENTS

The results obtained by Japanese and French investigators in the stimulation of plant growth by various non-essential elements were reviewed by Mr. P. W. Moore, a graduate student and fellow in the department. The original articles were all carefully studied and a critique in manuscript form made available. Experimental work was confined to boric acid and potassium iodide. Unquestionable stimulation, especially of the root system, in both water and soil cultures was obtained, and stimulation with boric acid appeared to give considerable promise of practical use in the culture of root crops, especially radishes. Mr. Moore's own conclusions are as follows:

"Both boric acid and potassium iodide are of undoubted value, at least in the culture of radishes. The optimum concentration for both appeared to be in the neighborhood of 750 grams (about 1½ pounds) per acre. For potassium iodide this is about ten times the dose recommended by the Japanese investigators. It corresponds fairly well with the dose of boric acid recommended by Agulhon for radishes. The bottoms are increased more than the tops. There seems to be no advantage in using both stimulants at once. If boron and iodine each perform some special function in the plant, then both of them together should be more beneficial than either by itself. Accordingly it is difficult to explain in this way the effect of stimulants, at least in the case of boron and iodine."

CHANGES IN CHEMICAL CHARACTER OF THE TEMPE DRAINAGE DITCH WATER

The opening of a ditch draining the alkaline area south of Tempe during the last summer offered unusual opportunity to study quantitatively the effect of drainage reclamation on the composition of the water and soil of the drained area. Consequently soon after water began to flow in the new ditch monthly samples were collected and analyzed. The results of the analyses are shown in Table XXII.

The very briny flow shown by the first analyses improved rapidly in composition as the ditch progressed and the flow increased. In September an unusually heavy rainfall raised the water table in the district and undoubtedly increased the flow, although there was no previous flow with which to compare, since the ditch is under construction and new areas are being added daily. The character of the drainage water has improved each month until in December the dissolved salts (or alkali) amounted to less than one-fifth that in the original flow. This is due to the improved character of the drainage encountered at or near the head of the ditch rather than to actual sweetening of the drainage at any one point, although such sweetening is undoubtedly occurring. After the completion of the ditch, improvement in the quality of the flow will be attributable to draining off the stagnant alkaline water and its replacement with purer drainage water. The remarkable change in composition with the probability of further im-

provement promises well for the use of the drainage water for irrigating lands on the Indian reservation below. It would be inadvisable, however, to apply the drainage water too soon on valuable lands, since rapid and marked improvement may reasonably be expectel.

TABLE XXII. COMPOSITION OF WATER FROM TEMPE DRAINAGE DITCH, PARTS PER 100,000 (BY C. N. CATLIN)

Date, 1916	Total solids	Chlories as NaCl	Hardness (permanent) $CaSO_4$	Hardness (temporary) $Ca(HCO_3)_2$	Alkalinity Na_2CO_3	SO_4	CaO	MgO
June 25	1665.2	1170.0						
July 13	1359.0	993.51	107.44			172.58	97.64	65.2
Sept. 10	599.4	432.0	27.2	67.2		64.76	14.2	25.2
Oct. 10	418.0	303.0	13.0	66.4				
Dec. 8	312.6	228.0	5.4	64.0		30.49	14.6	15.75
Nov. 10	346.4	220.0	7.6	60.3		33.78	12.6	17.57

MISCELLANEOUS

The assertion has often been made that sorghum grown in arid regions produced syrup of poor quality due to excessive mineral salts. Recently a sample of sorghum syrup of apparently good quality prepared from cane grown near Yuma was examined in this laboratory. In the accompanying table a comparison is made of the Yuma product with analyses reported in Wolff's *Aschenanalysen* and Wiley's *Foods and Their Adulteration*. The Arizona syrup contains less than half as much mineral matter as Wiley's example, although it appears to be about the same concentration. It contains only a little more mineral matter than the average for raw sorghum sugar according to Wolff, and very much less than the molasses from raw sugar. We presume the samples reported by Wolff and by Wiley were produced in humid climates. One striking feature of the ash of the Arizona syrup compared with Wolff's sample is its relatively high sulphate content and relatively low chloride content as shown in Table XXIII.

TABLE XXIII. ASH CONSTITUENTS OF SORGHUM SYRUP AND SUGAR

	Wolff's Aschenanalysen		Wiley's Foods	Ariz. Station
	Raw sugar	Molasses from raw sugar	Sorghum syrup	Sorghum syrup
	percent	percent	percent	percent
Solids	...	...	76.0	74.0
Ash	1.67	5.10	4.0	1.83
SO_4 in ash	8.84	4.30	...	15.26
Cl in ash...	5.85	5.74	...	3.31

An interesting instance of water of opposite character and nicely adjusted supply from the same well comes to us from near Toltec in the Casa Grande Valley. The owner has installed a small pump with

shallow suction to fill an elevated tank for domestic use. The surface flow, which is agreeably black alkaline and soft, accumulates in the top of the well when the larger, deeper-set irrigating pump is at rest, but its volume is not sufficient to affect in any marked way the more abundant flow of most excellent hard irrigating water met at greater depths. The composition of the two waters is given in Table XXIV.

TABLE XXIV. COMPOSITION OF DIFFERENT WATERS FROM THE SAME WELL; PARTS PER 100,000

	Upper scanty flow domestic water	Lower abundant flow irrigating water
Solids at 110° C.....	30.0	39.0
Chlorides as NaCl....	1.8	3.0
Permanent hardness as $CaSO_4$	...	4.3
Temporary hardness as $Ca(HCO_3)_2$	20.6	23.5
Black alkali as Na_2CO_3	3.4	...

A. E. VINSON,
Biochemist.
C. N. CATLIN,
Asst. Chemist.

IRRIGATION INVESTIGATIONS

CASA GRANDE VALLEY

The groundwater investigations outlined in the last Annual Report have been prosecuted. A mass of data on the groundwater table has been accumulated, but since movements of groundwater may be very slow, it is possible even now to draw only tentative conclusions. The gauging stations at Tucson have been maintained, and new stations established on the bridges and culverts on the Arizona Southern Railway between Red Rock and Sasco, and on the Southern Pacific Railway between Picacho and Maricopa. The floods of the year were very fortunate from an investigator's standpoint, inasmuch as they were unusually large, yet not destructive to the bridges on which the gauging stations depend. Special efforts were made to obtain the highest possible accuracy in the measurements at Sasco in order to obtain the true discharge at that point, where the Santa Cruz debouches into the Casa Grande Valley. Condensed records of the stream flows are given in Table XXV.

TABLE XXV. RUN-OFF RECORDS FOR SANTA CRUZ AND RILLITO RIVERS IN 1915 AND 1916

Month	1915		1916					
						So. Pacific Ry. culverts		
	Santa Cruz at Tucson	Rillito near Tucson	Santa Cruz at Tucson	Rillito near Tucson	Santa Cruz near Red Rock	Picacho to Casa Grande	Nunez*	Maricopa
	acre ft.	acre ft.	acre ft.	acre ft.	acre ft.	acre ft.	acre ft.	acre ft.
Jan.	10400	21500	24700	37400	20690	4300	500	1800
Feb.	11200	25700	600	2220	0	0	130	310
Mar.	3070	10200	0	3630	0	0	0	0
Apr.	4	1220	0	58	0	0	0	0
May	0	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0	0
July	60	5	2720	920	720	0	0	0
Aug.	0	0	8210	7840	4040	220	0	170
Sept.	0	0	1340	690	130	1500†	4600	560
Oct.	0	0	140	28	0	0	0	0
Nov.	0	0	0	0	0	0	0	0
Dec.	0	0	0	0	0	0	0	0
Total	24730	58600	37700	52800	25580	6020	5230	2840

*Flow at Nunez is to westward. This flow returns north at Lirim.
†September flood was caused by local rainfall.
Note: For previous records of Santa Cruz and Rillito at Tucson see Bull. 64, Ariz. Agr. Exp. Sta., 1910, and subsequent annual reports.

It will be seen from the table that practically all of the Santa Cruz run-off was absorbed into the ground and the residual flow that reached the Gila River was a small percentage of the total. The sum of the Santa Cruz and Rillito discharges near Tucson in 1916 was 90,500 acre-feet. Of this amount 64,900 acre-feet sank into the river bed between the Tucson gauging stations and Sasco, a distance of 32 miles, while the remaining 25,600 acre-feet passed Sasco. Just west of Sasco the stream divides, part flowing northwest to Eloy and part west to an abandoned reservoir and thence northwesterly to Maricopa. Of the former portion the amount that reached Eloy was 4500 acre-feet. This amount is again subdivided and probably less than one-third of it reaches the Gila. Of the second portion only 2200 acre-feet reached Maricopa.

The water table in the Casa Grande Valley, as studied by means of wells, does not show so marked reactions to the periods of flood flow as might be anticipated, and it is believed that to a considerable extent the water seeps downward to depths of less than 40 feet and is returned to the atmosphere through transpiration. Borings with a soil augur in land recently overflowed indicatel a penetration of six feet or less.

Slight effects on the water table are produced by seepage from the Florence canal, while the irrigation of about 800 acres west of Casa Grande appears to contribute considerably to the groundwater, thus indicating an important result that may be expected if the San Carlos dam is built and irrigation becomes general.

The effect of pumping has been studied at those wells which are most used. In general it may be said that interference can be noted for distances up to one mile. Interference between wells is bound to be a difficult problem in the future when the draught upon the groundwater supply is increased.

THE ANTELOPE VALLEY

A reconnoissance inspection of the Antelope Valley was made February, 1916. Contrary to previous belief, this valley has great possibilities of agriculture under irrigation. This is due mainly to the discovery of excellent water-bearing gravels underlying the fine sands in which previous attempts have been made to obtain water for irrigation.

The most difficult problem confronting the valley is that of protecting the valley lands from destruction by the great floods which occur at infrequent intervals. At the outset there should be adopted a definite policy of building homes on safe ground along the margins of the valley, from which as a base the agricultural land can be worked without danger of a calamity. This is the European system, and is not only adapted

to, but necessary in the Antelope Valley and in some other localities in Arizona that are exposed to occasional heavy floods.

TRANSPIRATION STUDIES

In order to study the relationship between duty of water and transpiration, evaporation, and altitude, three sites have been chosen, one each near Yuma, Mesa, and Willcox. Special studies will be made to test the hypothesis that the duty of water is measurable by the evaporation rate. In cooperation with the U. S. Weather Bureau, an evaporation station, equipped with an anemometer, a rain gauge, thermometers, and a pan of the new standard lesign, has been established at each station.

Special studies have been made, also, of transpiration from trees in the San Pedro Valley.

STATION PUMPING PLANTS

A new pumping plant was installed at the Sulphur Spring Valley Dry Farm during the past year. It was desired to obtain a flow of 100 gallons of water a minute for supplementary irrigation. The well is an 8-inch hole, 130 feet deep, bored with an auger and cased with light weight galvanized perforated metal. The depth to the water table is 75 feet. The capacity of the plant for domestic supply was 7.3 gallons a minute. The corresponding drawdown was obtained and found to be 20 inches. On the hypothesis that the discharge is proportional to the drawdown, even over a wide range, it was believed that the well would yield 100 gallons a minute with a drawdown not exceeding the suction limit for that moderately high altitude. The fact that the principle was confirmed by the test after the new plant was installed is of interest and importance.

The limiting conditions, namely, the small bore of the well, the high lift, and the low capacity, led to the selection of the Luitweiler, a high-grade double-acting reciprocating pump. The double-action is obtained with heart-shaped cams in such manner that the power required is constant, and the efficiency is very high. Most double-action pumps are misrepresented in this particular, and are no more efficient than single-action pumps. When the small domestic-supply pump was removed it was found that the well was not straight. Consequently the pump rods of the Luitweiler rub on each other, increasing the load. Although a small engine (6-horsepower) was provided in the design, it is able to pull the load satisfactorily, but the well should be straightened or a new one drilled at an early date.

An earth reservoir, 60 feet inside diameter, has been built close to the well, and the water can be discharged either into it or into an elevated 3000-gallon tank, which is of suitable height for house service and fire protection. The discharge from the reservoir is through a steel slide gate and over a weir, and the stream used ordinarily will be about 400 gallons a minute.

A new plant has been designed for the Salt River Valley Farm, also, and the well has been completed. The original design was for a drilled well, but the prices quoted, even for an 8-inch well, were so unreasonable, and the log of the Tempe Canal Company's wells a mile away was so favorable, that a well of the reinforced concrete caisson type was decided on. Anticipating loose gravel, as in the canal company's wells, the caisson was built heavy and strong, and is an excellent example of permanent construction. The well was sunk to a depth of 15 feet below the water level and 40 feet below the ground surface. The log is as follows:

Soil	2 feet
Caliche	10 feet
Sand and gravel	16 feet
Cemented gravel	6 feet
Sand and gravel	6 feet
Cemented gravel	

Comparison of this log with those of the canal company wells and wells to the southward shows that the Experiment Station Farm near Mesa is situated on an old Pleistocene ridge or bajada while the others are in Recent valley fill, at least to depth sufficient to give a good irrigation supply. The new well yields 110 gallons a minute, ample for domestic purposes and gardens, but not for general field irrigation. The use of groundwater for irrigation in the Salt River Valley should be encouraged to permit of an extension of the irrigated area, and all information regarding the location of groundwater supplies is of value and should be assembled.

An experience of interest to pump irrigators was had at the University Farm at Tucson. The discharge from the horizontal centrifugal pump dropped to 590 gallons a minute. It was observed that considerable air was coming out with the water and the air was found to be leaking in through the gland packing in spite of a water seal. On resetting the packing and tightening the gland the discharge increased to 650 gallons and by replacing the worn packing with fresh, the discharge increased to 720 gallons, the normal amount, with no change in the engine or pump speed. It is notable that the capacity of the pump could be reduced 18 percent by a moderate air leak. At another time the capacity was reduced about a fourth by a small stick which became

lodged in the impellor passages, throwing the pump out of balance and causing vibration and noise. Reduced capacity of a pump has many baneful results including lower plant efficiency, increased percentage of seepage loss in ditches, longer periods of pumping and increased cost. The gland and the joints in the suction pipe should be watched.

TEST OF PUMPING PLANT

A new pumping plant was tested on the ranch of the Agricultural Products Corporation in Pima County. The plant consists of a 15-inch, 52-foot type C. H. C. Layne & Bowler vertical turbine pump and a 35-horsepower Commercial oil engine. The pump has six stages, one more than usual for the same conditions, thus permitting of a slow speed when irrigating and a speeding up when pumping for the high service or in case the water table should fall during drought years. The pump was purchased with high fuel economy guarantee and the guarantees were not reached in the first tests. An expert from the engine factory visited the plant and made a number of changes after which the guarantees were made good, and the plant is now very efficient. Some of the changes were lengthening of the connecting rod one-half inch to increase the compression pressure, change in shape of end of fuel nozzle to give better atomization, lengthening inlet valve spring to reseat valve more quickly, advancing the ignition to about 35°, and restricting the cooling water circulation. The first named was the one most effective and shows that purchasers should insist on the optimum degree of compression even though locality where the engine is to be located is at a high altitude. The plant tests are given in Table XXVI.

TABLE XXVI. TESTS OF PUMPING PLANT AT CONTINENTAL, ARIZONA

Date	Engine speed	Discharge	Static lift	Fuel consumption
	R. P. M.	gal. per min.	gal. per hour	feet
Nov. 9	246	1140	59	4.16
Nov. 20	236	1030	58	3.26
Nov. 25	238	1070	58	3.04

In order to ascertain whether it was the pump or the engine that did not meet the specifications, a prony brake was put on the engine, and brake tests were made for capacity and fuel economy. With No. 1 engine distillate, the engine would carry a load of only 32 horsepower, but with tops of 42° B. it carried 35 horsepower. The brake tests were made on November 24 before the connecting rod was lengthened.

TABLE XXVII. PRONY BRAKE TESTS OF COMMERCIAL ENGINE AT CONTINENTAL, ARIZONA

No.	Load	Speed	Output	Fuel consumption	Fuel economy
	pounds	R. P. M.	H. P.	gal per hr.	H. P. hrs. per gal.
1	148.5	233.0	33.2	3.77	8.80
2	148.5	223.2	31.8	3.75	8.48
3	148.5	232.0	33.1	3.83	8.63

The important conclusions to be drawn from these tests are:

1. Both the capacity and the fuel economy of oil engines decrease with altitude.

2. The engines built in California should be rated more liberally; they should have some reserve power at an altitude of 2800 feet.

3. The clearance space should be reduced as the altitude increases.

4. Tops fuel oil of 40° to 44° B. gravity can be burned perfectly in well-designed 4-cycle engines and will give more power per gallon than engine distillate (50° B.)

GUARANTEES FOR PUMPING MACHINERY

A common difficulty in the purchase of an engine and pump is in securing a satisfactory guarantee. Guarantees in the past have been of such a character that it was impossible for the purchaser to ascertain whether or not the plant fulfilled the guarantees. Many selling agents, usually transients in the State, have taken advantage of this fact by making guarantees which could not be fulfilled. Tests could not be made and the impositions have not been discovered. This office has prepared a standard form of guarantee and has requested dealers in pumping machinery in Arizona to adopt it. With a very few exceptions they have consented.

CONCRETE WATER AND OIL TANKS

Several times in the past farmers have requested assistance in designing concrete tanks for holding water or engine fuel oil. Some of the tanks thus built have proven very successful and when once in use and made water-tight, they are far more durable than the more common galvanized iron tanks. The two problems involved are those of reinforcement and water-tightness. The first is capable of exact computation and the second requires only expertness in the proportioning and mixing of the concrete, a task which should not be undertaken alone by the ordinary farmer, though he might succeed with other forms of concrete construction.

Recently a 50,000-gallon tank was designed in this office. The walls are 6 inches thick of 1:2:4 gravel concrete, washed inside and out with two coats of neat cement. When put in service, the tank was filled one-third full of water and allowed to stand 24 hours; it was then filled two-thirds full and allowed another day's rest; then it was filled full. Much of the lower half of the surface sweated considerably after the second and third fillings, the upper half scarcely at all, and after fifteen days all sweating ceased. Hydrated lime was used in all but one ring of the concrete. The effect on the water tightness was sufficient to justify recommending it.

If the tank is to be used for tops fuel oil, it should first be made to hold water for at least two weeks until it is thoroughly watertight. The water appears to have an action causing colloids in the concrete. It is not to be recommended that concrete tanks be built for storing gasoline or engine distillate.

Additional Field at University Farm

Early in 1916 this Department was asked to make plans for the grading of a new field and for an extension of the cement pipe line at the University Farm. A contour survey was first made and platted and the grading was designed with a view to equalizing the cuts and fills and to make the haul a minimum. While this method has not been considered necessary by farmers, it is advisable whenever a competent surveyor is available. The lands were graded to several slopes so that a study can be made of the relation between the slope and head of water and the "efficiency of irrigation," that is, the uniformity of distribution.

Six hundred and thirty feet of 12-inch pipe and 570 feet of 16-inch pipe were used in the extension of the pipe line. In the old pipe line the water was discharged through notches in the sides of rectangular concrete boxes. One of these boxes was placed at the middle of the head end of each land making the boxes 36 feet apart. In part of the new pipe line similar boxes were used, and in the remainder of the line cement pipe risers* and California alfalfa valves were used. These risers are made by cementing a joint of pipe into the top of the pipe line, so as to make a tee, and the valve frames are cemented into the tops of the risers.

Because of the flat slope in which this pipe line was laid it was important to know in advance just what the loss of head would be. Tests were made on the old pipe line and it was found that in straight sections without outlets the loss of head was the same as is given in friction

*See Bul. 236, Office of Exp. Sta., U. S. D. A.

tables for cement pipe†; but in the sections with the rectangular concrete boxes placed 36 feet apart the loss of head was increased 66 percent. Later tests made on the new pipe line with circular pipe risers in place of the boxes showed that the loss of head was increased 35 percent over the smooth, straight pipe with no outlets.

Improvements were made in the irrigation practice at the University Farm. Lands which were laid out too long originally were cut in two and a new pipe line was laid to serve the lower ends.

IRRIGATION CONFERENCE

An irrigation conference was held at the University January 14-15, 1916. Invitations were sent to irrigation engineers, managers, zanjeros, and farmers, and a good attendance was secured. Six meetings were held and the program included papers by delegates from the Pecos, Rio Grande, Salt River, Yuma, and Imperial valleys, and the Supervisor of Irrigation of the U. S. Reclamation Service. Many problems that are common to all irrigated districts were discussed and much helpful information was disseminated.

SILO AT UNIVERSITY FARM

The Department also supervised the construction of a concrete silo at the University Farm. The inside diameter of the silo is 12 feet and the height inside is 34 feet, of which 29 feet are above ground. The walls are 6 inches thick, reinforced with hog wire fencing and a few half-inch round rods. The general design was the same as that recommended by the office of Public Roads and Rural Engineering, U. S. Department of Agriculture. The base was spread and was made unusually heavy on account of the low bearing power of the soil upon which the silo is founded. A concrete chute was built over the doors and ladder from eight feet above the ground to the top. The chute has walls three inches thick, reinforced with hog wire and steel rods, and was cast at the same time as the main walls of the silo. The construction of the silo was delayed a little by the extra time needed to set the somewhat complicated forms for the chute, but it is believed that the added convenience of the chute will more than justify the cost.

G. E. P. SMITH,
Irrigation Engineer.
A. L. ENGER,
Assistant Engineer.

†Bulletin 55, Arizona Agricultural Experiment Station, Cement Pipe for Small Irrigating Systems and Other Purposes.

THE WEATHER

Since the year 1908, the Weather has not been given separate consideration in the Annual Report. Although general climatic conditions necessarily remain the same, it seems well to mention again, as a preface to the 1916 report, those factors which determine the climate of Arizona—climate meaning the conditions of its atmosphere as regards heat or cold and moisture or dryness, manifested in a succession of weather changes throughout the year.

Arizona lies between the 31st and 37th parallels north latitude. This geographical location gives, at lower altitudes within the State, a semi-tropical temperature, characterized by hot summers and short temperate winters. As there is no large body of water contiguous to any part of its area, and none of the moisture-laden breezes from the Pacific reach Arizona because of intervening mountains, the region, as a whole, has what is termed an inland, arid climate. The air is very dry and the precipitation slight. Southern Arizona is the only section of the United States having more than 80 percent of the possible amount of sunshine. Temperature, as a rule, decreases 3 degrees F. for every 1000 feet of elevation above the sea level, and precipitation increases 5.8 inches for every 1000 feet. Arizona, therefore, with its altitudes varying from less than 90 feet in the Colorado Valley to nearly 13,000 feet on the highest mountain tops, shows great differences in temperature and precipitation in various localities.

The Weather Bureau of the U. S. Department of Agriculture records the climatological data for 144 different places in Arizona. Obviously so complete a report is not possible in this brief discussion. Kingman, Flagstaff, and the Prescott Dry Farm in the northern half; the Yuma Date Orchard, Phoenix Weather Bureau, the State University at Tucson, and the Cochise Dry Farm in the southern half of the State, have been chosen as representative points because of their locations and differing altitudes, and because of the connection of the five latter with, or proximity to agricultural work carried on by the Experiment Station.

The following tables have been compiled from data published by the U. S. Weather Bureau. Table XXVIII records climatological data for the past eight years and in a measure brings up to date the discussion in the Nineteenth Annual Report. It serves as the basis for some generalizations concerning the climate of the State, and also for noting the departures from normal, if any, for the year 1916.

TABLE XXVIII. CLIMATOLOGICAL DATA FOR THE PAST EIGHT YEARS

		1909	1910	1911	1912	1913	1914	1915	1916
Kingman Elev. 3326 ft.	Highest Date	*	110° F. July 21	110° July 15	105° Aug. 8	109° July 11	107° June 28	117° Aug. 20	107° June 18
	Lowest Date	14° Dec. 4	14° Jan 6	11° Dec. 26	17° Feb. 24	8° Jan. 7	*	21° Jan. 26	16° Dec. 24
	Last killing frost in spring	May 14	May 8	*	*	Apr. 15	*	Mar. 5	Feb. 3
	First killing frost in autumn	Oct. 4	Oct. 13	Nov. 12	Nov. 29	Dec. 4	Nov. 27	Nov. 10	Oct. 6
	Total precipitation	*	*	*	*	3.81	10.36	13.52	11.44
Flagstaff Elev. 6907 ft.	Highest Date	91° F. July 12	91° July 20	85° June 26	85° June 5	90° July 5	86° June 27	88° Aug. 20	86° June 16
	Lowest Date	—12° Dec. 24	—22° Jan. 5	—16° Dec. 31	—19° Jan. 3	—23° Jan. 11	—13° Dec. 15	—9° Mar. 3	—25° Jan. 31
	Last killing frost in spring	June 9	May 7	June 3	July 5	June 29	June 3	May 22	May 27
	First killing frost in autumn	Sept. 22	Sept. 28	Oct. 3	Sept. 22	Sept. 24	Oct. 4	Sept. 14	Sept. 24
	Total precipitation	22.75	18.25	26.	17.69	15.7	17.57	25.54	23.38
†Prescott Dry Farm Elev. 5068 ft.	Highest Date	97° F. July 13	97° May 29	95° July 6	95° June 5	101° July 6	96° June 27	97° Aug. 19	95° June 15
	Lowest Date	1° Dec. 19	—6° Jan. 6	—2° Dec. 31	—1° Jan. 3	1° Jan. 7	12° Dec. 15	11° Nov. 14	7° Jan. 12
	Last killing frost in spring	May 30	May 6	June 1	May 15	Mar. 24	May 1	May 3	Apr. 1
	First killing frost in autumn	Oct. 5	Oct. 13	Oct. 3	Sept. 22	Nov. 4	Nov. 15	Oct. 15	Nov. 6
	Total precipitation	21.81	13.29	22.59	23.97	11.18	13.96	19.95	16.14
Yuma Date Orchard Elev. 135 ft.	Highest Date	112° F. July 14	120° May 30	115° July 31	115° June 5	115° July 10	115° Aug. 3	112° Aug. 19	110° Aug. 31
	Lowest Date	26° Dec. 4	25° Jan. 4	22° Dec. 26	29° Dec. 29	24° Jan. 6	33° Dec. 14	22° Dec. 17	22° Jan. 12
	Last killing frost in spring	*	Feb. 18	Jan. 3	Feb. 26	Jan. 12	None	Feb. 4	Mar. 25
	First killing frost in autumn	Dec. 4	Dec. 27	Dec. 12	Dec. 25	Dec. 4	None	Nov. 12	Nov. 22
	Total precipitation	8.63	3.93	2.79	3.11	1.04	3.70	4.22	2.30

Continued

Table XXVIII—Continued.

		1909	1910	1911	1912	1913	1914	1915	1916
Phoenix Elev. 1108 ft.	Highest Date	110° F. July 13	114°	109° July 31	111° June 5	110° July 5	110° June 27	111° Aug. 10	111° June 15
	Lowest Date	25° Dec. 5	23° Jan. 6	22° Dec. 26	26° Jan. 3	16° Jan. 7	28° Dec. 15	27° Jan. 18	24° Dec. 9
	Last killing frost in spring	Feb. 24	Feb. 18	Feb. 13	Jan. 29	Mar. 1	Feb. 7	Mar. 3	Feb. 2
	First killing frost in autumn	Nov. 16	Dec. 23	Nov. 26	Dec. 19	Dec. 5	Dec. 8	Nov. 13	Nov. 13
	Total precipitation	6.17	4.32	14.12	6.87	5.39	8.98	9.41	6.76
State University, Tucson Elev. 2425 ft.	Highest Date	108° F. July 14	111° May 29	107° June 6	103° June 5	109° July 5	107° June 28	110° Aug. 19	107° June 15
	Lowest Date	17° Dec. 5	15° Jan. 6	16° Jan. 4	18° Dec. 6	6° Jan. 7	22° Dec. 15	19° Dec. 28	15° Dec. 11
	Last killing frost in spring	Apr. 7	Mar. 27	Feb. 20	Mar. 12	Mar. 27	Feb. 28	Mar. 7	Mar. 25
	First killing frost in autumn	Nov. 10	Dec. 21	Nov. 12	Oct. 29	Dec. 5	Dec. 7	Nov. 11	Nov. 8
	Total precipitation	10.21	9.80	11.25	9.84	9.32	19.9	12.62	13.15
Cochise Dry Farm Elev. 4250 ft.	Highest Date	106° F. July 13	104° May 29	102° Aug. 18	114° May 30	108° July 5	102° June 27	102° June 22	102° July 4
	Lowest Date	*	5° Jan. 6	—4° Dec. 25	*	0° Jan. 7	20° Jan. 21	14° Dec. 28	6° Dec. 11
	Last killing frost in spring	*	Apr. 17	*	*	*	May 2	Mar. 22	Apr. 15
	First killing frost in autumn	Oct. 7	Nov. 30	Oct. 22	Oct. 22	Oct. 27	Nov. 27	Nov. 11	Nov. 8
	Total precipitation	*	12.90	*	*	9.03	18.01	13.49	14.69

*Not given. †Prescott data 1909 to 1912 inc.

The terms "killing frost" and "freezing temperature" as far as damage to vegetation is concerned, are not strictly interchangeable. However, in an arid section, a killing frost seldom occurs until the temperature of the air has fallen somewhat below freezing point; and, moreover, the range in daily temperature being relatively great, the duration of freezing temperatures is shorter. Thus frost temperatures may often be experienced with little harm to vegetation. The growing season in the northern part of the State at the higher altitudes is very short, and hard freezes are common late in spring and early autumn. Destructive

frosts in central and southern Arizona are very uncommon, and when they do occur it is during December and January.

Referring to Weather Bureau reports for all points within the State, the mean annual temperatures for 1911, 1912, and 1913 were the lowest for many years. The minimum temperatures for 1911 and 1912 were not unusual, but the January freeze of 1913 was the most severe within the history of the State. On January 6, 7, and 8 the lowest temperatures ever known were recorded in nearly all sections. The maximum temperature is usually reached during June or July. May, 1910, was abnormally warm, breaking all previous records for May, and the temperatures of May 29 or 30 are, in most instances, the maximum temperatures reached during a period of many years. However, considering the high day-time temperatures of Arizona from a human standpoint, it must be remembered that the thermometer is not a reliable indicator of physical comfort. Heat is rapidly dissipated from the body by reason of excessive evaporation due to the extreme dryness of the atmosphere. This dryness, with almost constant breezes, renders the temperatures, that in more humid sections would be intolerable, easily endurable. The daily range in temperature is great, being from 30 to 60 degrees, and the resulting cooler nights during the hot season are most enjoyable.

There are two rainy seasons, the more distinct one beginning each year early in July and ending about the middle of September. The rains during this season are usually local and of short duration, but torrential in character. The other rainy season is not so well defined, and precipitation may occur in the early winter, or as is more usually the case, in February and March. Much of the precipitation at higher altitudes in the winter months is in the form of snow. So much depends on the timeliness of the rainfall that the total precipitation for the year is not a certain indication of its effectiveness. Although the average rainfall for the State for 1913 was but slightly below the normal, the year was exceptionally unfavorable for all interests dependent upon adequate and timely precipitation. Bulletins 64, 65, and 70 of the Arizona Agricultural Experiment Station contain excellent discussions of the character and extent of the rainfall of Arizona with its bearing on irrigation, grazing and agriculture.

Tables XXIX and XXX show some monthly and annual data for the year 1916.

The temperatures for the year for the State as a whole may be considered as about normal. A frost March 25 and 26 badly damaged

TABLE XXIX. MAXIMUM, MINIMUM AND MEAN TEMPERATURES FOR EACH MONTH AND FOR THE YEAR, AND THE NORMAL ANNUAL MEAN TEMPERATURE FOR 1916

Month	Kingman			Flagstaff			Prescott Dry Farm			Yuma Date Orchard			Phoenix			State University Tucson			Cochise Dry Farm		
	3326 ft			6907 ft.			5008 ft.			135 ft.			1108 ft.			2435 ft.			4250 ft.		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
Jan.	72°	20°	45.3°	48°	—25°	24.6°	*	7°	*	72°	22°	51.2°	69°	31°	50.8°	73°	23°	50.8°	71°	14°	45.2°
Feb.	*	21°	*	58°	— 8°	31.8°	70°	10°	45.2°	86°	27°	60.0°	82°	29°	59.6°	82°	22°	57.9°	80°	18°	51.0°
March	85°	31°	57°	69°	11°	40.2°	88°	24°	50.8°	99°	30°	65.3°	91°	38°	64.0°	90°	30°	61.6°	86°	28°	56.3°
April	102°	35°	64.3°	74°	17°	44.2°	82°	26°	54.4°	99°	38°	68.2°	95°	44°	68.2°	94°	34°	64.0°	89°	29°	58.6°
May	*	*	*	76°	19°	49.4°	84°	34°	59.4°	101°	41°	71.3°	100°	48°	74.0°	99°	44°	70.4°	95°	37°	64.6°
June	107°	40°	73.2°	86°	32°	58.9°	95°	44°	70.1°	107°	48°	80.6°	111°	57°	83.9°	107°	44°	80.2°	101°	42°	76.2°
July	105°	45°	77.9°	85°	39°	64.2°	95°	51°	73.6°	108°	55°	84.4°	110°	64°	89.0°	107°	63°	84.4°	102°	58°	78.0°
Aug.	100°	50°	78.0°	80°	38°	60.7°	89°	50°	71.2°	110°	56°	86.5°	106°	62°	87.0°	102°	63°	82.8°	97°	56°	75.2°
Sept.	98°	39°	70.8°	77°	30°	55.4°	90°	43°	65.8°	110°	51°	81.4°	104°	55°	80.9°	100°	52°	79.4°	91°	43°	70.8°
Oct.	82°	32°	58.8°	69°	21°	43.9°	75°	31°	53.6°	94°	38°	65.8°	89°	41°	66.2°	96°	38°	66.2°	86°	32°	60.7°
Nov.	84°	23°	50.2°	73°	6°	34.4°	80°	13°	44.4°	92°	27°	57.2°	88°	28°	55.8°	93°	24°	55.4°	85°	22°	49.5°
Dec.	73°	16°	39.8°	59°	—10°	25.6°	64°	*	*	79°	20°	48.8°	78°	24°	47.1°	79°	15°	47.0°	74°	6°	40.1°
For the year	107°	16°	*	86°	—25°	44.4°	95°	7°	*	110°	20°	69.2°	111°	24°	68.9°	107°	15°	66.7°	102°	6°	60.5°
Normal annual mean..			*			44.7°			*			*			69.4°			66.7°			*

*Not given.

TABLE XXX. MONTHLY AND TOTAL PRECIPITATION IN INCHES FOR 1916

	Kingman	Flagstaff	Prescott Dry Farm	Yuma Date Orchard	Phoenix	Tucson State University	Cochise Dry Farm
January..	2.70	8.16	4.33	.64	2.34	4.00	2.20
February	.64	.77	.31	.01	.13	.58	.48
March ...	.83	1.77	1.45	.25	.37	.50	.63
April	.18	.06	.41	T	.15	.51	.08
May	1.52	.37	.05	0	T	0	.28
June.....	0	0	0	0	0	.07	0
July	1.27	2.46	2.22	.67	.77	2.03	3.78
August...	1.57	3.29	2.66	0	.30	2.26	4.10
September	.72	1.78	1.13	T	1.66	1.29	1.55
October..	.71	3.61	2.65	0	.65	1.10	1.36
November	0	0	0	0	0	0	0
December	1.30	1.11	.93	.73	.39	.81	.23
Total for year....	11.44	23.38	16.14	2.30	6.76	13.15	14.69
Normal ..	11.16	22.73	*	*	7.90	11.93	11.78

*Not given.

fruit in the central and eastern counties. August and September were slightly cooler than usual. September had more than its normal precipitation, and excessive rains in the uplands north of Salt River Valley caused floods which broke the main canal and flooded a portion of the project, causing considerable loss to farmers as well as damage to the canal system. November, as compared with other years, broke all records for low temperature, dryness and abundance of sunshine. Although there were no unusual extremes of cold, the temperature of December was almost continuously below normal, and the precipitation was less than usual.

The total precipitation was slightly below that of the previous year. January, 1916, however, is the wettest month on record for many years. The melting of the December snows and the heavy rains caused floods throughout the State. According to reliable information, the high-water marks of the Salt and Gila Rivers this season have not been exceeded since 1891.

May, usually the driest month, had less than average rainfall this year, but June was still drier, the only appreciable precipitation being at Tucson. Farms without irrigation suffered.

As a whole, the weather conditions of 1916 may be considered as favorable to the agricultural and grazing interests of the state.

C. N. CATLIN,
Observer.

EDUCATIONAL

AGRICULTURAL INSTRUCTION IN THE UNIVERSITY

The healthy growth of the College of Agriculture is indicated by the graduation of eight students in June, 1916, with the degree Bachelor of Science in Agriculture, and one Bachelor of Science doing major work in agriculture. The present senior class numbers eight, most of whom will probably be graduated in June, 1917. The enrollment in the College of Agriculture since its organization in 1908 is as follows:

		Students
1908-1909	2-year course and others	9
1909-1910	2-year course and others	15
1910-1911	2-year course and others	26
1911-1912	2 and 4-year courses and others	38

	2 and 4-yr. courses and specials	Other students electing agriculture	Total receiving instruction in agriculture
1912-1913	26	27	53
1913-1914	29	9	38
1914-1915	41	7*	48
1915-1916	59**	3*	62
1916-1917 (1st semester only)	51**	1	52

*Including one student in the College of Arts and Sciences majoring in agriculture.
**Including two graduate students.

During the first years that instruction in agriculture was given the organization was that of a department rather than a college. Consequently all students taking agriculture were enrolled in the Agricultural course. These included preparatory students and students in the general Arts and Science courses. The number of these has diminished from year to year due to the withdrawal of preparatory work and to changes in the curriculum of the College of Arts and Sciences by which applied sciences, including agriculture, were segregated and no longer accepted as meeting the requirement in pure science. These losses in numbers have been equalized by new enrollments in the College of Agriculture.

The organization of the College of Agriculture has been strengthened materially by cataloging the work of the college, formerly all classified as agriculture, in five distinct departments, Agricultural Chemistry, Agronomy, Animal Husbandry, Horticulture, and Plant Breeding. By the fortunate combination of the Agricultural College

with the Experiment Station the services of men engaged in research under our peculiar conditions can be secured as major professors. Likewise opportunity is afforded the student in many instances to familiarize himself with investigations being carried out by the members of the Experiment Station Staff. The curriculum has also been strengthened by adding new courses. Through the cooperation of the Department of Zoology in the College of Arts and Sciences a course in Entomology is being given for the first time. This enables the College of Agriculture to train men for horticultural inspection work as well as to round out the general instruction given in horticulture and agronomy. Further cooperation with the other colleges of the University is contemplated.

The Agricultural student body has shown excellent spirit during the year. They have entered heartily into the affairs of the general student body and have contributed much to social and athletic life on the campus. The Agricultural Club has held regular meetings with interesting and instructive programs carried out for the most part by the students. The Staff of the Experiment Station has also held a monthly Agricultural Science Seminar which, while not primarly for the student body, has been open to them and some have improved the opportunity to attend and take part in the discussions.

AGRICULTURAL INSTRUCTION IN THE STATE

In accordance with Paragraphs 2791-2797, Laws of 1913, granting state aid to high schools and normals for instruction in agriculture and industrial arts, twenty-one schools have qualified. Of these nine are offering courses in agriculture ranging from a single year's work in general agriculture to more or less specialized four-year courses. The other twelve institutions receiving state aid are devoting it to industrial courses, including home economics but exclusive of agriculture. While the statistics at our disposal are too incomplete for publication we feel that the teaching of agriculture in secondary schools deserves more attention than is being given. One or two elective units of the high school curriculum can be given to such instruction, even in the mining districts, with advantage to the individual and to the State, especially to pupils who do not contemplate taking a college course in agriculture. Those contemplating a college course, however, should be advised to take the regular college preparatory course with just enough agriculture as free elective to arouse and hold their interest in the subject.

FARMER'S SHORT COURSE

The fourteenth annual Farmer's Short Course was held for two weeks in January, 1916, with a total enrollment of 163, including 35 women in home economics. This was the first short course organized with sections for different interests meeting simultaneously. With the increasing attendance this division becomes more and more practicable, and the farmers in attendance can be given a wider range of instruction from which to select what suits best their own needs. At the fifth annual Farmer's Short Course, lasting for one week only in January, 1917, three sections were given for farmers and one for the women in home economics. The attendance in 1917 reached 250 with 144 women in home economics. The growing attendance at the short courses justifies the invitation of specialists from beyond our own borders to come and give our farmers the newest and best each year in carefully chosen fields. The information and enthusiasm carried home by those attending are having a marked influence in bettering agricultural conditions in the State. The growth of these courses during five years has been:

	Registered Attendance
1913	80
1914	103
1915	143
1916	163 including 35 in Home Economics
1917	250 including 144 in Home Economics

R. H. FORBES,
Dean.
A. E. VINSON,
Professor Agr. Chem.

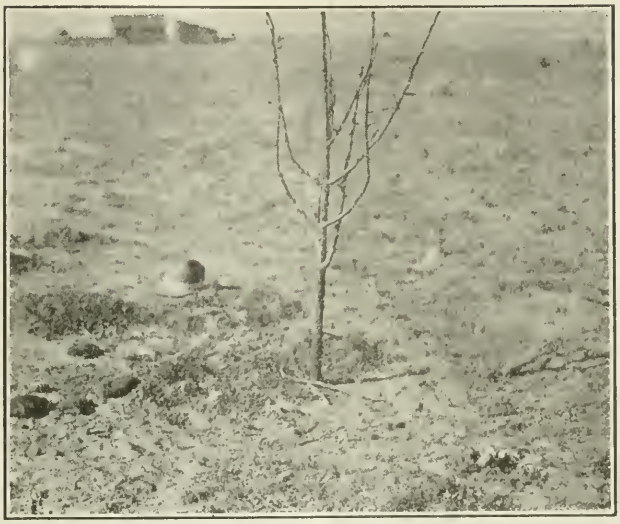
AGRICULTURAL INSTRUCTION EXPENDITURES FOR THE YEAR ENDING JUNE 30, 1916

		Administrative	Agronomy	Horticulture	Animal Husbandry	Dairying	Plant Breeding and Botany	Totals	
Morrill Fund (Federal)	Salaries	$ 850.00	$1836.55	$1650.00	$1200.00	$1430.00	$1470.00	$8436.55	
	Educational supplies	.....	.....	78.40	43.45	550.00	.....	671.85	$9108.40
Univ. Farm sales fund	Departmental expenses	454.28	.....	22.13	329.34	793.12	.....	1598.87	
	Feedstuffs	.....	.....	.....	.....	.....	.....	580.08	
	Farm implements	.....	.....	.....	.....	.....	.....	684.39	
	Pumping expense	.....	.....	.....	.....	.....	.....	516.72	
	Freight and express	.....	.....	.....	.....	.....	.....	189.07	
	Auto repair and supplies	.....	.....	.....	.....	.....	.....	459.54	
	Building and repairs	.....	.....	.....	.....	.....	.....	57.43	
	Miscellaneous	.....	.....	.....	.....	.....	.....	540.26	$4626.36
Univ. Farm fund (State)	Salaries and wages	.....	.....	.....	.....	.....	.....	6424.86	
	Feedstuffs	.....	.....	.....	.....	.....	.....	543.14	
	Farm implements	.....	.....	.....	.....	.....	.....	24.23	
	Auto, repair and supplies	.....	.....	.....	.....	.....	.....	608.82	
	Poultry houses	.....	.....	.....	.....	.....	.....	1052.58	
	Poultry (birds)	.....	.....	.....	.....	.....	.....	235.43	
	Clearing land	.....	.....	.....	.....	.....	.....	520.42	
	Farming	.....	.....	.....	.....	.....	.....	105.74	
	Miscellaneous	.....	.....	.....	.....	.....	.....	198.74	$9713.96

University of Arizona

Agricultural Experiment Station

Bulletin No. 81



Young apple tree gnawed and killed by rabbits. These pests do an immense annual damage to gardens and orchards and to field crops. It would greatly pay every farming community to inaugurate community rabbit drives and otherwise cooperate in killing off these destructive animals.

How to Combat

Rabbits, Gophers, Prairie Dogs, Coyotes, Ants and Grasshoppers

By Arthur L. Paschall

Tucson, Arizona, November 15, 1917

UNIVERSITY OF ARIZONA
AGRICULTURAL EXPERIMENT STATION

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(Regents of the University)
Ex-Officio

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The State Superintendent of Public Instruction.

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DeLore Nichols, B. S.,.....County Agent, Coconino County
Hester L. Hunter,.....Secretary Extension Service
Frances M. Wells.....Secretary Agricultural Experiment Station

The Experiment Station offices and laboratories are located in the University Buildings at Tucson. The new Experiment Station Farm is situated one mile west of Mesa, Arizona. The date palm orchards are three miles south of Tempe (cooperative, U. S. D. A.), and one mile southwest of Yuma, Arizona, respectively. The experimental dry-farms are near Cochise and Prescott, Arizona.

Visitors are cordially invited, and correspondence receives careful attention.

The Bulletins, Timely Hints, and Reports of this Station will be sent free to all who apply. Kindly notify us of errors or changes in address, and send in the names of your neighbors, especially recent arrivals, who may find our publications useful.

Address,THE EXPERIMENT STATION,
Tucson, Arizona.

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Fig. 1.—Young apple tree, headed much too high in order to prevent jackrabbits from cutting off the scaffold branches. Note that trunk of tree is painted with a repellant. A good rabbit-proof fence inclosing the orchard is the best protection from these pests.

How to Combat

Rabbits, Gophers, Prairie Dogs, Coyotes, Ants and Grasshoppers

By Arthur L. Paschall

Predatory animals and insect pests are doing much damage to crops, gardens, orchards, and the ranges, in many parts of Arizona. Many inquiries are being received from those who want to know how best to combat these pests. It is to meet this demand and answer these inquiries that this publication has been prepared.

No attempt has been made to give the life history of the several species discussed. The writer's intention has been to afford the best and most recent information for the extermination or control of pests in as brief a form as possible, to meet the requirements of busy people. The methods given are thoroughly practical.

RABBITS

Speaking in a general way, there are two kinds of rabbits, the large jackrabbits (two species), and the smaller cottontails. The best time to combat both kinds is in winter when their natural food is scarce. This is also when they do the most damage.

RABBIT DRIVES

While jackrabbits are usually more destructive than cottontails they are also easier to control by means of community rabbit drives, which is the most rapid way of getting rid of them. In carrying out such a drive the whole community should be interested and every one over ten years old should take an active part.

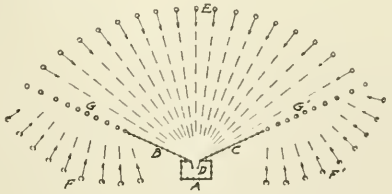

Fig. 2.—Plan of rabbit drive.

Plan of drive

The pen, *A*, should be of sufficient size (usually about 20′ x 20′) to hold the rabbits of an ordinary drive. It should be made of stout close-mesh woven wire fence, 5 ft. high, with the bottom wire 3 to 4 inches under ground to prevent the rabbits from digging out. The wings, B and *C*, must also be of sufficiently close-meshed wire so that the smaller

rabbits will not get through. The fencing need not be as high as that for the pen, wire 24 inches high, or more, being suitable. The wings should be as long as they can be made. One mile is not too long, but a shorter length should catch many rabbits. These wings lead to a small opening, *D*, in the pen. The people in the drive form a semi-circle in front of the pen and wings, as shown by the small circle, *E*. The distance apart of the drivers and the distance from the pen depends upon the country, whether brushy or open grass land. In brushy country the drive should be short, perhaps one mile; while in open grass land the drives may extend over two to five miles. The people should carry tin pans, or other objects with which to make a noise and frighten the rabbits along, especially when beginning the drive and while the drivers are far apart. The drivers should walk at about the same gait, towards the pen, as shown by the arrow points. Other drivers may be formed in two flanks, one on each side. These will drive towards the front of the pen and form the lines *C G, B G* before the line *E* approaches them. *No guns should be allowed,* for these may cause accidents; but each driver should carry a light club with which to kill the rabbits as they try to run through the line when it closes in near the pen. The clubs are also to be used for killing the rabbits in the pen.

In some localities there are farmers who have fenced large fields with rabbit-proof wire fencing. In such places, these wire fences may be used to great advantage for rabbit drives, by using the wire fence for one of the wings of the drive, as shown in the following diagram:

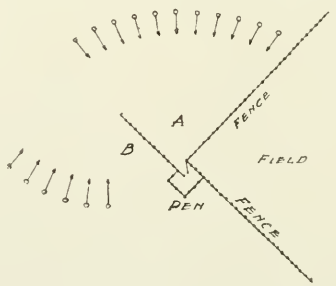

Fig. 3.—Fencing used for rabbit drive.

The drivers should be placed in a semi-circle, the flank on the side B driving rabbits towards the front where they will then be driven towards *A* and into the pen. It sometimes happens that there is a farm on each side of the road fenced, with the corners coming near each other on opposite sides of the road in such a way as to form the two wings, in which case the pen can be put in the road as shown. The writer remembers such an instance, near Cochise.

In case there is no rabbit-proof wire fence to be used as above described, woven wire may be attached to ordinary pasture or field fence posts. If there is any farmer in the community who is buying woven wire to fence a field he should be induced to first loan his wire fencing to the community for use in a rabbit drive. Sometimes hardware dealers will rent fence wire to the farmers for this purpose, the farmers each contributing to the cost of the loan while the merchant deducts the rental from the sale-price of the wire on account of unrolling. Usage for this purpose does not ordinarily damage the wire.

Where a large number of people engage in a drive many rabbits may be killed without the use of wire. The people form a large circle and gradually close in. In this way the rabbits are huddled together in the center where they become confused and can be clubbed easily. *No guns should be allowed.*

TRAPPING

An effective trap can be made by using a pen similar to the one mentioned for the drive, but smaller (10 x 14 ft.) and with a "goose-neck" entrance, as shown in the following figure:

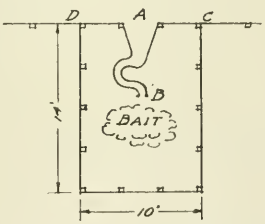

Fig. 4.—Pen trap with gooseneck entrance.

The opening at *A* should be about 3 ft. wide and the end of the entrance alley *B* should be narrowed down to 8 inches. The rabbits enter this trap and are unable to find their way out, unless they be left in the pen for several days. These traps may be made along garden fences, in which case *C* or *D* may be the corner of the fence. Attractive bait such as alfalfa, corn, sweet potatoes, etc., should be placed in the runway and inside the pen. This form of trap is more effective for jackrabbits, but will also often catch cottontails.

For cottontails the following is a very effective trap: Nail 4 pieces of 1 x 12 inch boards, 2 ft. long, together to form a box without end pieces. A goods box may be used for this. Set the box in the ground directly under the woven wire fence, so that the bottom wire of the fence is 4 or 5 inches above the top of the box. Have a trap door on the top of the box as illustrated (Fig 5). The rest of the fence should have the

bottom wire well underground so that the rabbits will not dig under it. The rabbits will run along the fence, looking for an opening. They will attempt to pass under the fence over the box, when the trap door will drop and let them into the box.

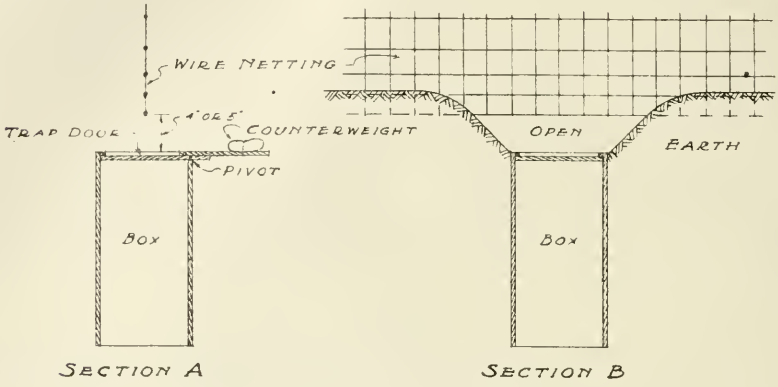

Fig. 5.—Pitfall trap to be placed under fence.

This form of trap has been found very effective. One farmer stated that he found from 4 to 6 cottontails in each trap for each of several mornings, until the number of cottontails was materially reduced.

In firm soil, instead of putting a box in the ground a pit is dug, and a trap door, with supporting frame, can be used with equal effectiveness.

Another rabbit trap, for cottontails, is made of two 1 in. x 6 in. boards, *A* and *B*, 3 ft. long and with two short cross pieces, *C* and *D*, at each end. Two pieces 1 in. x 5½ in., about 2 ft. 3 in. long (*E* and *F*) are nailed or fastened with screws at *G*, one end of the trap is placed beneath the woven

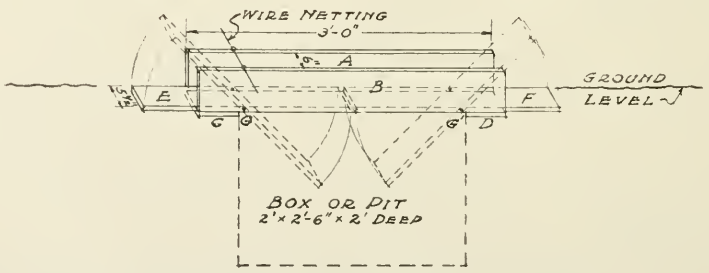

Fig. 6.—Another form of pitfall trap, for hard ground.

wire at a point where the rabbits have been entering, the trap being inside of the garden or field. Undr the trap is a pit or box in the ground. When the rabbit gets near the center of the board, *E* or *F*, the board tilts and lets it fall into the pit or box. This kind of trap is being used in the San Simon Valley

with great success. Many rabbits are being trapped in one of these in a single night. A door in the side of the pit or box can be arranged, through which the rabbits can be removed.

During late fall and in winter cottontails make excellent human food, and the young ones are good to eat at all times of the year. Young jackrabbits are also good to eat during fall and winter, if they are soaked overnight in salt water to which a little baking soda has been added. This will remove the "wild" odor and taste.

Rabbits of all kinds make excellent food for poultry. Even poisoned rabbits may be used for this purpose without danger of poisoning fowls, or other animals, provided the head, stomach and intestines are removed and buried. Strychnine acts upon the nerves and kills the animals before it is absorbed into the circulatory system. One jackrabbit per day fed along with a grain ration is sufficient for 35 to 40 hens. The rabbits may be ground or chopped finely, or if fed fresh, may be cleaned and then nailed to a post for hens to pick at.

POISONING

Both jackrabbits and cottontails can be controlled and largely exterminated by systematic poisoning. However, care should be exercised in using poisons. The U. S. Department of Agriculture, Bureau of Biological Survey, recommends as follows:

"When the law permits, poison can often be used to advantage, especially at times when the natural food of the rabbit is scarce. The following formulas have been employed with considerable success:

"*Alfalfa poison:* Dissolve 1 ounce of strychnine sulphate in 2 gallons of boiling water and sprinkle over 16 pounds of leafy alfalfa hay, chopped in 2-inch lengths. The poisoned hay may be scattered in small heaps along rabbit trails in inclosures from which stock is excluded.

"*Grain poison:* Mix together 1 ounce of powdered strychnine (alkaloid) and 1 ounce of baking soda. Sift this into 1 pint of thin hot starch paste and stir thoroughly. (The starch paste is made by mixing 1 heaping tablespoonful of gloss starch in a little cold water, which is then added to one pint of hot water and boiled until a clear thin paste is formed. Add one-tenth ounce of saccharine and stir.

"Apply to 12 quarts of oats, rolled barley, milo maize or feterita. Mix well until grain is evenly coated. Use as directed for alfalfa poison. If the powdered strychnine alkaloid is not available, strychnine sulphate crystals may be used if prepared as for prairie dogs.

"This same creamy paste can also be applied to orchard prunings. The smaller twigs should be cut up into 2 or 3 inch lengths and the poison applied in the same way as with oats.

"*Poisoned green baits:* Cut up a supply of sweet potatoes, carrots, parsnips, apples, or other similar baits into cubes ½ to 1 inch in diameter. Insert in each a small quantity of powdered strychnine or a small strychnine crystal. When a larger quantity is to be prepared, the powdered

strychnine can be dusted over the bait by means of a salt shaker in the proportion of ⅛ ounce of strychnine to 2 quarts of the baits.

"The poisoned grain, prunings, or green baits are dropped along rabbit trails or in places frequented by the rabbits, care being exercised in placing them to *prevent any possible injury to live stock.*"

Rabbits are especially fond of sweet potatoes and these are therefore better than alfalfa for poisoned bait.

Several years ago the writer killed large numbers of rabbits, mainly jackrabbits, on the plains of Texas, where the rabbits were numerous, by mixing a little powdered strychnine with salt, dampening this so the wind would not blow it away, and placing it in rabbit trails and along woven wire fences, out of reach of stock. In portions of the Southwest where there are alkali spots or "salt licks" to which the rabbits resort, this salt bait may not be effective; but where they cannot obtain salt readily the poisoned mixture would be effective.

The following salt bait has been used successfully in Oregon:

2 quarts salt
1 quart sugar
1 oz. powdered strychnine

One tenth of an ounce of saccharine may be substituted for the one quart of sugar and would be much better.

Put this mixture out in small heaps of 1 to 2 tablespoonfuls each on hard ground where stock will not get to it.

Still another poisoned bait for rabbits consists of

1 lb. powdered arsenic
1 gal. bran
1 qt. molasses

Mix thoroughly and spread small quantities in rabbit runways as the sun is going down.

PROTECTION AGAINST RABBITS

The surest method of securing against damage by rabbits is to fence against them. For this purpose a woven wire fence at least 30 inches high should be used. It is more economical to put in a fence of good, stout wire than one of small and weak wire, like common poultry netting, which cannot usually be stretched taut. The mesh should be small enough to prevent cottontails and young jackrabbits from getting through. One to one and one half inch mesh should extend to 16 inches above ground, and then the openings may gradually increase. Cottontails have the bad habit of digging under fences. To insure against this the bottom strand should be stretched taut upon the surface of hard ground, or 3 to 4

inches beneath the surface of soft ground. All washes or other openings beneath the fence should be securely closed and the field should be inspected occasionally to see that no fresh openings have been made. If such are found they may be closed immediately or a trap set in the opening. One or two rabbits will usually do much damage to a garden or young orchard in a single night.

Farmers who live in the same section of land can economize by cooperating in fencing their farms. Where there are four farmers in the same section, each having 160 acres, they can reduce their rabbit-fence expense by fencing the whole section on the outside, instead of fencing each farm separately. The expense of fencing can be reduced further if the people in the same locality will club together and purchase wire and posts in carload lots.

Tree protection: Individual tree protectors of woven wire, wood, paper, straw, etc., are good to defend trees against cottontails, but these do not protect the lower branches from jackrabbits. The writer has seen many young fruit trees, the branches of which had been cut off above the protectors by jackrabbits.

One farmer in the San Pedro Valley states that he paints his young fruit trees with nicotine oil and finds that the rabbits do not injure the trees; while the rabbits destroyed trees in a nearby orchard which were not protected. This, or any other oil or paint, should not be applied to the foliage, or to very young and tender twigs, as it may kill them. Young trees just set out may also be injured and even killed by a coating of grease or thick paint, as this coat will close the pores in the bark. These "paints" are not poisonous but are repellants. One tablespoonful of nicotine extract—"Black leaf 40", to ½ gallon of whitewash is also effective as a repellant.

The following formula is from one of the U. S. Department of Agriculture Weekly Press Letters:

Poisoned tree wash: "Dissolve 1 ounce of strychnine sulphate in 3 quarts of boiling water and add ½ pint of laundry starch, previously dissolved in 1 pint of cold water. Boil this mixture until it becomes a clear paste. Add 1 ounce of glycerin and stir thoroughly. When sufficiently cool, apply to trunks of trees with a paint brush. Rabbits that gnaw the bark will be killed before the tree is injured."

Note: It is probable that ½ pint of molasses may be substituted for 1 oz. glycerin.

This poisoned wash has proved highly satisfactory in the West and promises to be one of the most popular methods of protecting trees from rabbits.

NATURAL ENEMIES

Owls, large hawks and coyotes are animals that prey upon rabbits and other animal pests, such as prairie-dogs, gophers, rats and mice. Hawks (except the small "darters" or chicken hawks) and owls should be protected. They are very valuable in destroying harmful animals and they do practically no damage. Once the rabbits are materially reduced in number or nearly exterminated by drives, trapping and poisoning, these animals will usually keep them in such check that their damage will be negligible.

GOPHERS

The following formula for the control of gophers is recommended by the U. S. Department of Agriculture Bureau of Biological Survey:

DIRECTIONS FOR DESTROYING POCKET GOPHERS

"Pocket gophers are readily caught in several makes of special traps commonly on the market, and a few of these suffice to keep small areas free of these pests. For ridding alfalfa fields, orchards, and long stretches of ditch embankments of them, a very successful and much more practical method is to poison them by placing baits of sweet potato or of parsnips in their underground runways.

"The baits should be cut about an inch long and a half inch square, and washed and drained. From a pepper box slowly sift ⅛ ounce of powdered strychnine (alkaloid) and 1-10 of this quantity of saccharine (ground together in a mortar or otherwise thoroughly mixed) over about four quarts of the dampened baits, stirring to distribute the poison evenly.

"The runways, which are usually 4 to 8 inches beneath the surface, can be located by means of a probe made of any strong handle an inch in diameter and 36 inches long. One end should be bluntly pointed. Into the other should be fitted a piece of ⅜ inch iron rod, protruding about 12 inches, and bluntly pointed. A foot rest aids in probing in hard soils. By forcing down this iron rod near gopher workings, or a foot or two back of fresh mounds, the open tunnel can be felt as the point breaks into it. The blunt end of the instrument is now used to carefully enlarge the hole, a bait or two is dropped into the run and the probe hole closed.

"One soon becomes expert in locating the runs, and a man can treat 300 to 500 gopher workings in a day. Baits need be placed only two places in each separate system of 10 or 30 mounds, which is usually the home of a single gopher. In our experience baits placed fairly in the open runs have invariably killed the gophers. The method has found great favor wherever it has been introduced."

The writer has used poisoned bait made from sweet potatoes according to this formula and found it to be entirely satisfactory. He has also given demonstrations in making and using this poisoned bait and reports of satisfactory results have been received. Messrs. D. A. Gilchrist and Duane Stonier, assistants in the extermination of predatory animals, with the U. S. Biological Survey, rendered excellent assistance in this work during the fall of 1916 and winter of 1916-17.

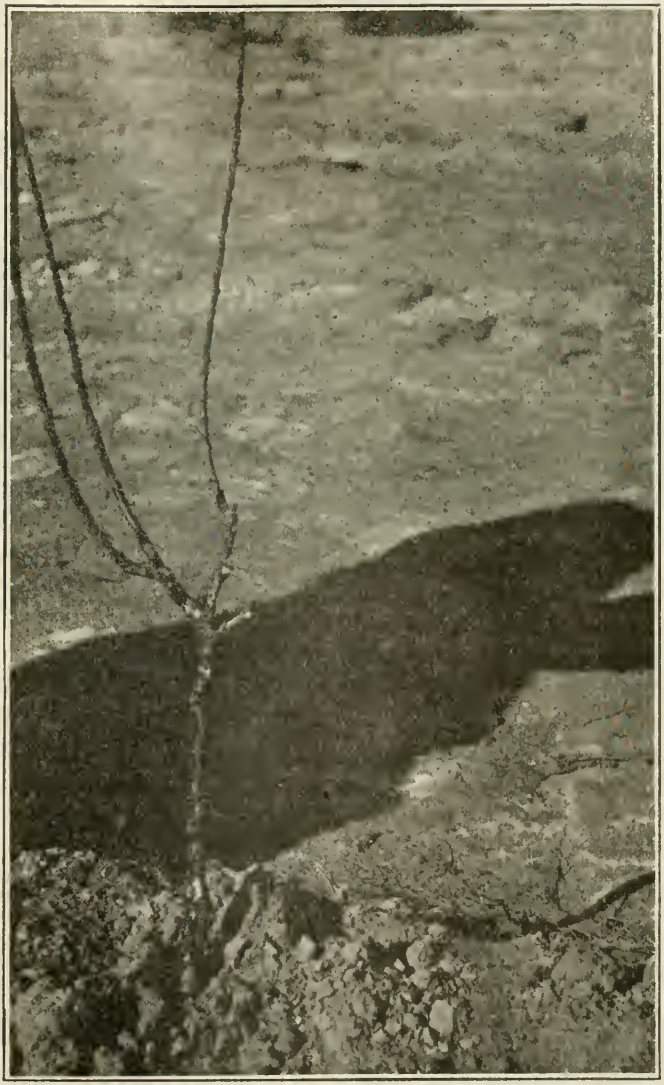

Fig. 7.—Note the gopher holes and small mounds around this dead apple tree. Gophers do much damage to crops as well as to orchards and gardens. They are especially troublesome about reservoirs and irrigation canals and ditches.

PRAIRIE DOGS

Prairie dogs are found scattered over large areas within the State, mainly in the northern and in the southern portions. They spread very rapidly. According to record the first prairie dogs found in the Sulphur

Fig. 8.—Which shall have the grass—the cattle, which are valuable, or the prairie dogs and harvester ants, which are of no value? Prairie dogs and ants destroy grass, roots and tops, and also cause the soil to become washed away by flood waters. Use poisoned grain for the prairie dogs and London Purple for the ants.

Spring Valley were discovered near Willcox about 40 years ago. They are now infesting at least 200 sections of land in this valley, and there are many other sections which have been infested by these pests on which the "dogs" have destroyed the grass and have moved away.

It does not take long for prairie dogs to destroy the grass on an area infested by them. They eat the crowns and roots of grasses, and they usually destroy the best pasture grasses first. They also prevent the reseeding of the grasses by cutting down the seed stalks, in their efforts to maintain an open view of their towns. It has been estimated that 20 prairie dogs, with their normal increase, will eat or destroy as much grass in a year as a cow will consume. But this is not all the damage they do, for in destroying the protective grass sod they leave the land bare for erosion, especially *on* slopes and hillsides. In such districts "washes" will occur which gradually increase in size, until grasses cannot again establish themselves. The writer has observed many such places. In other regions where the erosion is not so great, especially in sandy soil, when the prairie dogs are killed off and the cattle are kept off for one to two years, the good grasses reappear.

Besides large areas of prairie dog-infested land in the Sulphur Spring Valley, there are many sections of infested grass land in the San Pedro

Valley near Hereford, and westward toward the Huachuca Mountains; and in the upper part of the San Simon Valley. The grass on much of these 250 sections in the county has been destroyed, and is rapidly being destroyed on the balance of this area.

Assuming 250 sections of land in Cochise County infested by these animals, a conservative estimate of the value of this area before the prairie dogs reduced it may be made from the number of cattle it would support. Twenty-five acres of average range in Sulphur Spring Valley will support one yearling for one year. Two hundred and fifty sections, 160,000 acres, will therefore support 6,400 yearlings which at a value of $25 each would be worth $160,000. This is a conservative estimate of the annual damage doen by these pests in one county.

The means by which to prevent this enormous loss is to exterminate the prairie dogs by poisoning them. This work should be planned, undertaken and carried out on a community, state-wide basis, although individuals can profitably keep them killed off their own land. The State Legislature (Session laws of Arizona, 1917, Chapter 48) has provided that, upon petition of 100 residents of any county a tax of one-half mill may be assessed, and the resulting fund used to purchase and prepare poisons and distribute them to landholders for use against rodent pests. This law should be strengthened by compelling every landowner to kill the "dogs" on his holdings. This should apply, also, to state and school lands. The National Government, through the Biological Survey, will co-operate by killing the "dogs" on Forest Reserves and the public domain, as it is now doing in the northern part of the State. Advisory assistance may also be rendered to communities and individuals.

According to the U. S. Biological Survey there are seven species of prairie dogs. There are two distinct species in Arizona,—the small species in the northern part of the State and the large species, which is found in the Sulphur Spring Valley. According to Mr. D. A. Gilchrist of the U. S. Biological Survey, who has charge of predatory animal extermination work in Arizona, and who has had experience in poisoning these pests in both sections of the State, the small northern species hibernates during winter. This species, therefore, must be poisoned in spring and summer, when the grass is good, and hence it is more difficult to kill with poisoned bait than the southern species which is active the entire year and can be killed easily by putting out poisoned bait in winter, spring or late fall. However, in Cochise County, best results have been secured by poisoning during the dry months of March, April and May.

Mr. Gilchrist and the writer tested milo, feterita, wheat and rolled barley for poisoned bait for prairie dogs in the Sulphur Spring Valley.

We found that rolled barley was most effective. Excellent results were obtained by making and applying bait according to the following formula, recommended by the U. S. Biological Survey:

DIRECTIONS FOR POISONING PRAIRIE-DOGS IN ARIZONA

"Dissolve 1 ounce of strychnine sulphate in 1½ pints of boiling water. Add 1 heaping tablespoonful of gloss starch, previously mixed with a little cold water, and boil until a clear paste is formed. Add 1 ounce of baking soda and stir to a creamy mass. Add 1-12 ounce of saccharine and ¼ pint of syrup and stir thoroughly. Pour over 13 quarts of rolled barley and mix well until every grain is evenly coated. Allow to dry before using.

"In bushel quantities use, as above directed, 2½ ounces strychnine, 2½ ounces soda, 1-5 ounce saccharine, 1¼ ounces starch, 1½ quarts boiling water and ⅝ of a pint of sirup.

"Scatter poison, when the natural food of the prairie-dog is scarce, on clean, hard places near the holes, 1 quart to 50 holes. *Do not put the poisoned bait in the holes.*

"If powdered strychnine alkaloid is used, prepare the hot starch paste first. Then sift strychnine and baking soda previously mixed thoroughly together, into the hot starch paste, and stir to a creamy mass. Proceed as in the above directions with sirup, saccharine, etc.

"In some localities in Arizona where the natural prairie-dog foods are abundant, success with poison has not always been obtained by the usual methods. In such cases excellent results may be secured by placing a very small quantity of clean rolled barley at each active hole and after two days treat the areas with poisoned grain prepared as in the above directions.

Caution

"All poison containers and all utensils used in the preparation of poison should be kept *plainly labeled* and *out of reach* of children, irresponsible persons, and livestock."

When poisoned bait is used according to the above direction—that is, about one small tablespoonful thrown down on hard earth near the hole, thus scattering the bait, there is no danger of poisoning stock.

In cases where it is desired that the prairie-dogs be killed off quickly while the natural food is plentiful, or where a farmer has only a few acres infested with prairie-dogs and does not care to use poisoned bait, carbon bisulphide ("high-life") may be used. This generally kills all of the animals with one application. It is more expensive to use than the poisoned bait. The following directions are recommended by the U. S. Biological Survey:

"One ounce (two tablespoonfuls) of carbon bisulphide should be poured on a small piece of cotton waste or other cheap absorbent material and placed well down the hole. Close the hole immediately with dirt or sod.

Every burrow which shows evidence of being used should be treated, and all holes should be closed with dirt. One gallon is sufficient to treat from 100 to 130 holes (an average of about 125 holes). This can be accomplished by one man in 2 to 3 hours.

"Less gas is absorbed by damp soil than by dry soil, hence carbon bisulphide is somewhat more effective after a heavy rain.

"Careful and judicious use should exterminate practically all of the animals from the area treated.

Caution

"Carbon bisulphide evaporates very rapidly, so it should be kept in tightly corked bottles or cans. *It is highly explosive and inflammable* and should never be brought near fire."

COYOTES

Coyotes are valuable animals for destroying rabbits, prairie-dogs and other small predatory animals; however occasionally they become so numerous as to attack and kill small calves, lambs and kids and to cause much damage by killing chickens and turkeys.

The following directions for poisoning coyotes is given by the U. S. Biological Survey:

"In poisoning coyotes it should be borne in mind that the animals are of more than ordinary cunning. Their ability to detect the whereabouts of a trap or the presence of poison in bait is remarkable. Great care should be taken in preparing the bait to avoid human scent, for the coyote seems to regard man as his worst enemy. In handling baits do not touch them with bare hands, but use a pointed stick or wooden forceps.

"*To prepare poisoned bait* place 3 grains of strychnine in a capsule and insert it into a piece of suet or cow's udder about the size of an English walnut, being careful to remove all strychnine from outside the capsule. Strychnine is very bitter and if not put into capsules will be detected as soon as taken into the mouth, and the animals, becoming suspicious, will not swallow the bait, especially if much poisoning has been done in the neighborhood. Baits should be allowed to stand in a wooden bucket about 48 hours before using to make sure that no human scent remains.

"Coyotes can be attracted to the poisoned baits by dragging a piece of meat (or fresh cowhide) behind a saddle horse over foothills and across trails where the animals come from the mountains to the valleys for food and water, and then dropping the baits along the path thus made. As the animals cross the path they will follow it and pick up and swallow the poisoned baits, as their attention is on the scent of the meat drag.

"Never poison a carcass, but wait until the coyotes have eaten half or more than half of the fress carcass, then place poisoned baits around the carcass, from 20 to 30 feet away.

"As coyotes are very fond of fruit, dried figs and prunes make good bait. Unless an attractive lure is placed near the baits to keep the animals busy until the strychnine takes effect, they may get away and go a long

distance before dying, as the capsule has to dissolve to free the strychnine."

It has been found that if poison is placed in a freshly killed animal (jackrabbit, dog, cat or other fresh meat) which is buried in the earth, the coyotes will dig it up and eat it and be killed by the poison, when they would not eat the uncovered bait.

ANTS

There are many species of ants, but the ones that cause the greatest damage and with which Arizona stockmen and farmers are especially concerned are the larger species of harvester ants. These are the large red ants that do so much damage to field crops, vegetables, young trees and other plants. The writer has seen young fruit trees killed by these pests, which eat the young twigs and buds. Gardens are sometimes ruined by them, the young plants being cut off at the surface of the ground. Fields of beans have been reduced to less than half stand, the young plants having been cut off just as they were breaking through the surface crust. In some of these cases farmers were at a loss to know why there was not a good stand, not having observed that the damage was done by ants. On one farm the writer found that harvester ants were cutting down the young plants in a Sudan grass field as fast as they came up.

Harvester ants not only destroy plants but they sometimes do much harm to animals, sometimes killing them. One woman stated that she lost 150 small turkeys that died from the effects of harvester ant bites. These pests often seriously annoy larger animals. A cow may lie down on a nest, when the ants will bite or "sting" her udder and teats, causing sores. Blackleg may also sometimes be traced to ant bites which cause wounds through which the germs find entrance. Harvester ants are also annoying to people, their bites causing pain and sometimes making sores. The effect of an ant sting is similar to that of a wasp sting, but is usually more painful and persistent.

Various methods have been used to exterminate harvester ants. Gasoline, coal oil, crude oil, cyanide of potassium and carbon bisulphide ("high-life") have been employed with varying degrees of success. The best, cheapest and most easily applied remedy for general use is London purple, the active poison in which is arsenic. It varies greatly in effectiveness. Only a good grade should be purchased. It costs about 25 cents a pound in 5 pound lots. Sprinkle a small circle of the powder around the opening of each ant nest, putting a little into the hole. A teaspoonful is usually sufficient for treating one nest. This should be applied in

dry weather, when the ants are active and when there is no strong wind to blow the powder away. The best time to begin the treatment is when the ants first become active in the spring. The application should be repeated at intervals of one week to ten days, as long as ants continue to show up. The poison acts slowly, killing the ants in one to three days. In crawling back and forth across the poison the ants get the fine powder on their legs and bodies and thus carry it into their nests and track it over their food supply.

Ants infesting houses should be traced to their nests if possible and destroyed by pouring in a small amount of coal oil or carbon bisulphide. These small ants are valuable in grain or seed bins. They destroy the larvae of harmful insects, especially pea and bean weevils, and grain weevils.

GRASSHOPPERS

Grasshoppers are on the whole the worst, or one of the worst, pests with which the Arizona farmer has to contend. Grasshoppers not only destroy crops, gardens, and fruit trees, but also do much damage to the range by destroying grass and mesquite bean crops.

Fig. 9.—Turkeys are great grasshopper destroyers. They should be herded in order that they may keep on the move and also that coyotes may not harm them. Herding an hour in the morning and an hour in the late afternoon and penning for the rest of the day and at night is a good plan to handle them. Some one in the community could well make a specialty of raising and herding turkeys, or taking them to raise and market on shares, thus doing a large enough business to afford to devote his time to it. (Note the boy in the background and also how the turkeys string out in a line).

In communities where these pests appear in large numbers and where the region is sparsely settled, it is difficult and expensive for a farmer who is surrounded by uncultivated land to save much of his crop. However, if active measures are taken in time grasshoppers can be controlled.

MEANS OF CONTROL

Poultry: Grasshoppers can be controlled and at the same time can be made profitable by raising turkeys to eat them. It is a good plan to herd the turkeys on grasshopper ground one to two hours in the morning and again in the afternoon. In this way they are prevented from damaging crops and are protected from hawks and coyotes. In order to herd at a profit one should have a sufficiently large flock to make it a paying business. Each farmer or farmer's wife in a locality can easily raise a few turkeys. As soon as these are large enough to be herded one man can buy them or take them to raise and sell on shares. Usually, as soon as turkeys are large enough to be herded, grasshoppers and other insects have made their appearance. When the grasshopper season is

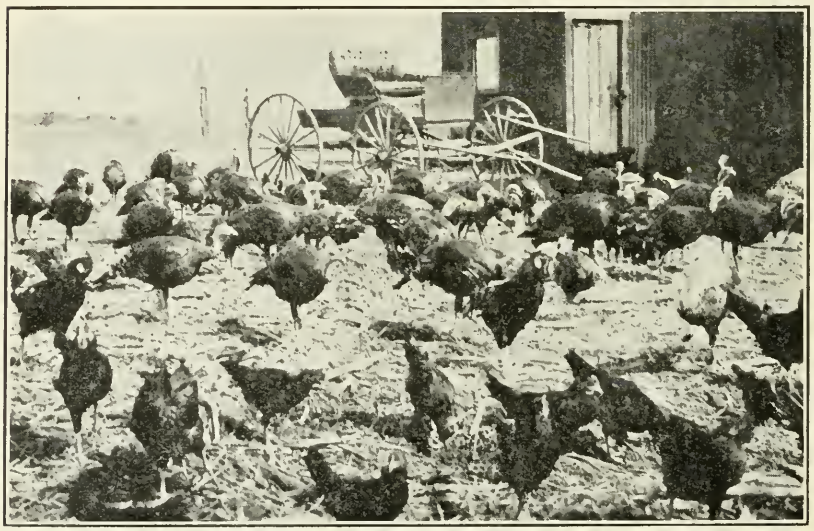

Fig. 10.—Turkeys and chickens thrive well in Arizona, are big assets to farms and are great insect destroyers.

over it requires but little feeding to make turkeys ready for market. This is a suggestion which every community troubled with grasshoppers should consider, since Arizona climate is favorable to successful turkey raising.

Chickens and guinea fowls, when allowed free range, are also very helpful in destroying grasshoppers and other insect pests. Every farm should maintain a good supply of pure-bred chickens. One farmer in a badly infested grasshopper district was protected from these pests by a large flock of White Leghorn hens.

Poisoning: In the absence of turkeys, poison baits are economical and effective for destroying grasshoppers. By the use of poisoned bran several

farmers in the badly infested areas of Cochise County saved their crops from destruction by grasshoppers in 1916.

The following methods of poisoning are recommended by the U. S. Department of Agriculture.

Grasshopper baits: "Ninety-five per cent of grasshoppers attacking crops in widely different parts of the country were killed quickly and cheaply by an improved poison bran bait and the Criddle mixture. The important change in the formula is to double the amount of lemons or oranges used in the bait, and to add these fruits to the Criddle mixture. The change in the mixture is recommended by the forage crop entomologists of the department as a result of thorough tests conducted in New England, Florida, California, and Arizona. These tests were conducted in different sections and with many different varieties of grasshoppers to determine, if possible, why the old formulas were only partially effective with adult grasshoppers and even less effective with young grasshoppers, and to find whether the fault lay with the different mixtures or with the way they were used. The entomologists found that adding the fruit to the Criddle mixture and increasing the amount in the bran bait increased the attraction of the bait to the grasshoppers and led them to eat it more readily.

New formulas for bran bait and Criddle mixture: The Criddle mixture as modified for use in killing young grasshoppers is prepared as follows:

50 pounds fresh horse droppings.
1 pound Paris green.
1 pound salt.
3 oranges, finely ground.

Ordinarily no fruit at all is used in the Criddle mixture, and but three oranges to each 25 pounds of bran bait.

"The poison bran bait, as modified with the especial object of killing young as well as old grasshoppers, is prepared as follows:

25 pounds wheat bran.
1 pound Paris green.
2 quarts cheap molasses or blackstrap.
6 oranges or lemons.

"Thoroughly mix together the bran and Paris green in an ordinary washtub or other vessel. Into a separate receptacle, containing the molasses or sirup, squeeze the juices of the fruit. Chop up finely the skin and pulp of the fruit and add to the molasses. Dilute with 3 gallons of water and mix with the bran. Add enough more water to bring the whole to a stiff dough.

"The bait should be sown broadcast early in the morning, before sunrise, in strips 1 rod apart, over the area to be treated, so that the grasshoppers may be attracted to it before it dries out. The most satis-

factory method of distributing the bait is to sow it from the rear end of a buggy." Farmers in the Rucker district of the Sulphur Spring Valley report that they have secured best results from poisoning by putting out the poisoned bait between 11 a. m. and 11 p. m. At this time of day, during the hot and dry days, the grasshoppers seem unusually thirsty and will travel a long distance for the moist bait.

Hopperdozers: Grasshoppers are found usually in large bunches soon after hatching out. If these are discovered before they begin to fly they can be exterminated cheaply by the use of 'hopperdozers,' provided conditions are favorable for their use. (For further information on hopperdozers see Timely Hint No. 104 of the Arizona Experiment Station).

When grasshoppers are hatched out in areas that contain much dried grass, the pests may be destroyed by burning off the grass. A circle on the outside should first be set on fire so that the hoppers cannot escape.

In regions where grasshoppers are likely to occur the people should keep a strict lookout in the spring and early summer in order to determine where they first appear, so that control measures may be applied before the young grasshoppers begin to fly or destroy vegetation. Clubs should be formed for this purpose and regular reports made by the members in order that there may be community cooperation.

REFERENCES

For further reference and reading matter on the subject of agricultural and range pests the reader will find the following publications very interesting and instructive:

Farmers' Bulletin No. 335: Harmful and Beneficial Mammals of the Arid Interior.

Farmers' Bulletin No. 702: Cottontail Rabbits in Relation to Trees and Farm Crops.

Farmers' Bulletin No. 670: Field Mice as Farm and Orchard Pests.

Farmers' Bulletin No. 369: How to Destroy Rats.

Farmers' Bulletin No. 587: Economic Value of North American Skunks.

Farmers' Bulletin No. 747: Grasshopper Control.

Bureau of Biological Survey Bulletin No. 20: Coyotes in their Economic Relations.

Bureau of Biological Survey Bulletin No. 40: A Systematic Account of the Prairie Dogs.

Bureau of Biological Survey—Circular No. 61: Hawks and Owls from the Standpoint of the Farmer.

Reprint from Yearbook for 1907. U. S. Department of Agriculture. The Rabbit as a Farm and Orchard Pest.

University of Arizona

Agricultural Experiment Station

Bulletin 82

Rootstocks on seedling Johnson grass plant

Johnson Grass Control

By H. C. Heard

Tucson, Arizona, December 1, 1917

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Visitors are cordially invited, and correspondence receives careful attention.

The Bulletins, Timely Hints, and Reports of this Station will be sent free to all who apply. Kindly notify us of errors or changes in address, and send in the names of your neighbors, especially recent arrivals, who may find our publications useful.

Address, The Experiment Station,
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PREFACE

For about thirty years Johnson grass has spread, at first slowly and then with increased rapidity, at altitudes of 4000 feet and below, throughout Arizona. In some cases its introduction was no doubt accidental; but in other instances it is known to have been planted by irrigating farmers as a hay crop, and by stockmen as an emergency forage. Johnson grass is therefore now well distributed over grazing ranges, along water courses, and throughout the lower irrigated valleys of the State. While this plant, with its fleshy rootstocks, may serve beneficially as an emergency forage, and as a soil binder to prevent erosion, its main effect is as a pestiferous weed in irrigated valleys, preventing the profitable culture of summer crops and depreciating land values seriously.

The State has endeavored to regulate this weed by means of a law prohibiting all traffic in Johnson grass plants and seed, or its culture, but with little effect upon the pest.

Many attempts have been made by the farmers themselves to exterminate or control Johnson grass. Continuous dry fallowing of infested fields is practiced; sheep are to some extent being used along ditches and weedy roadsides; and "easy methods" of soil treatment by chemicals, steam, or otherwise, have been proposed; but more and more it is being found that intelligent and persistent cultural methods based on a knowledge of the plant and the effective use of crop rotations, are most certainly successful. Intensive cultivation of valuable summer growing crops, such as cotton and Indian corn, is perhaps the most effective means of disposing of Johnson grass, seconded by winter growing crops of grain, lettuce and various vegetables.

Not only may Johnson grass be effectively and economically controlled by cultural methods, but a benefit may be derived from it, inasmuch as it is observed that old Johnson grass land enriched with quantities of organic matter derived from decayed rootstocks is more productive than ordinary soil. In 1917, 41 to 50 bushels of wheat per acre were grown at the Salt River Valley farm on land that had been badly infested with Johnson grass.

It may be, therefore, that Johnson grass, like some other apparent misfortunes, handled with energy and determination, will prove a blessing in disguise.

R. H. Forbes,
Director.

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F g. 1.—Vigorous Johnson grass rootstocks.

Fig. 2.—Johnson grass rootstocks exhausted by close-grazing with sheep.

Johnson Grass Control

(Sorghum halepense)

INTRODUCTION

For several years the need for data on the control of Johnson grass in the irrigated valleys of Southern Arizona has been manifest. An excellent opportunity for experimental work in the eradication of this weed under average farm conditions was offered when the Agricultural Experiment Station began to operate the Salt River Valley Farm near Mesa. Half of this tract of land was infested with a perfect stand of Johnson grass and about 40% of the other half of the farm was very heavily seeded to the weed.

As is well known, Johnson grass at an intermediate stage in its growth sends out a fleshy rootstock in which is a considerable quantity of stored up substances, capable of supplying new plants formed at the nodes of this rootstock. As a result, if the above-ground part of the plant is destroyed, food materials stored in the rootstock are capable of producing new foliage, which, after it again has made a slight growth, is maintained by its fibrous roots and by the nutritive processes which are carried on in the leaves and stems. Since the growth of all of the higher plants is dependent upon plant foods derived from two sources; first, the soil solution through roots, and second, from the air by means of synthetic processes carried on in leaves and stems and assisted by sunlight; and since neither is sufficient in itself to maintain the life of the plant, the destruction of Johnson grass may be accomplished by cutting off one of these sources of supply, thus forcing the stored up substances in the rootstocks to maintain the plant, continuing this process until the reserves in the rootstocks are exhausted. Two means of thus disturbing the normal processes of Johnson grass plants were chosen; the destruction of the stems and leaves by cultivation, and by close-grazing with livestock. For the latter method sheep were selected.*

*Acknowledgements.—The writer desires to state that the experimental work leading to this publication was planned by Professor John F. Nicholson prior to his departure in February, 1917, the program being carried out and the publication written by himself.

It was also deemed advisable to attempt the control of Johnson grass by reducing the vitality of the rootstocks by exposing them to intense sunlight, sun-heat, and aridity. It appeared desirable to supplement this method with more or less cultivation.

In carrying out the above plan six fields were laid out:

Field C, a 40-acre tract, was set aside to be held fallow from the time of removal of a wheat crop in June, 1915, until December, 1916, at which time another grain crop was to be planted. After the removal of the second crop, when the land was sufficiently freed from Johnson grass, it was planned to seed it to alfalfa.

Field D, containing 20 acres, had been in sorghums for a number of years until November, 1915, when it was plowed and seeded to barley. After the removal of the barley crop plans were made to pasture the field with sheep until such time as the Johnson grass should be under perfect control.

Fields E and F, each containing 10 acres, were set aside for the use of summer crops which demanded considerable cultivation. The crops chosen were Egyptian cotton and dent corn, to be alternated each year.

Field G, containing 20 acres, was to be dry fallowed during the summers and planted to grains during the winters.

Field H also contained 20 acres on which a continuous dry fallow was to be maintained until the experiment should close.

OPERATIONS IN DETAIL

FIELD C; SUMMER FALLOW, WINTER GRAIN

Following the removal of wheat in June, 1915, Field C was kept dry and plowed during the following August, being left rough throughout the succeeding winter. Early in the spring of 1916 there was a luxuriant growth of volunteer grains. The summer plowing of the previous year had very greatly reduced the vitality of the Johnson grass rootstocks and almost all of the weed that was evident in the spring of 1916 was a seedling growth which had been germinated by the winter rains just preceding. To prevent these seedlings from attaining sufficient maturity to send out new rootstocks the land was again plowed in April, 1916. Summer rains caused the germination of still more seed and a third plowing was made in August, 1916, prior to seeding small grains in December. At the time of seeding virtually no old Johnson grass plants with appreciable vitality were noted. The small grains planted at this time were harvested in June, 1917, and the land was left dry until August at which time it was plowed prior to seeding to alfalfa in November. By the time of this last plowing

almost all of the Johnson grass had been destroyed and without question the pest can easily be controlled in future by digging out the very few remaining plants with a shovel or a grub hoe.

FIELD D; SUMMER PASTURE, WINTER GRAIN

The stand of Johnson grass on this field in 1915 was about as heavy as could be grown. It was plowed in November of that year and seeded to barley in December. The perfect stand and vigorous growth of barley in the spring of 1916 served to hold the Johnson grass well in check until the harvest in May. At this time the land was sufficiently dry to prevent rapid growth of Johnson grass without irrigation. In the middle of June, 1916, the land was irrigated and enough sheep were turned in to graze closely all edible weeds. In order to force the Johnson grass to send out new foliage and thereby hasten the exhaustion of the rootstocks the irrigations which followed were frequent enough to keep the land very moist at all times. In a very few weeks a marked diminution in the vigor of the grass was noted and, to supply winter pasture to supplement the growth of the Johnson grass in late fall and early spring, the land was thoroughly disked in November and seeded to barley in December. Part of this crop, which was more than sufficient for the needs of the sheep, was harvested in June, 1917, at which time the Johnson grass appeared to be destroyed. In September it was again plowed preparatory to seeding for pasture and hay purposes, and by the middle of November the remaining Johnson grass plants were so few that a few hours' work of one man sufficed to clean up entirely the 20 acres.

FIELD E: INTENSIVE CULTIVATION, COTTON AND CORN

This 10-acre tract, which was very foul indeed (see Fig. 3), was partially mowed and burned over in the fall of 1915. In February, 1916, it was plowed preparatory to planting to cotton. Considerable leveling was necessary and to facilitate this the land was irrigated twice. Soon there was a solid mass of Johnson grass over the entire field and in spite of the fact that the leveling necessitated replowing in March the effect on the Johnson grass was negligible. The cotton was planted about the middle of April and in a couple of weeks was almost hidden by the growth of the weed. Cultivation with sweeps, which cut every bit of vegetation within their path, was started early in May and hoes were used at the same time to chop out the weeds in the cotton rows. A great deal of hoeing and cultivating was necessary for the next two months, by which time the vigor of the Johnson grass had materially diminished. It was very easy to keep the grass in check the remainder

of the summer, and by December, 1916, virtually no Johnson grass was noticed in the field except that which had grown from seed brought in with the irrigation water used during July and August. At the time of the germination of these plants the cotton was too large to permit of further cultivation, which would easily have destroyed the seedlings. In January and February, 1917, this land was plowed preparatory to a green manuring crop to be turned under before planting to corn. Accordingly the field was irrigated and late in March tepary beans were drilled in very thickly. These beans came up readily and at

Fig. 3.—Field E, August, 1915.

first made satisfactory progress, but due to the lack of nitrogen fixing bacteria in the soil their growth during May was slow. At the same time Johnson grass plants, which had come up from rootstocks developed on the seedlings introduced by the irrigating water of the previous July and August, appeared in such great numbers that the beans were plowed under very early in June. Johnson grass again came up and made necessary the use of a weeder in late June. In the middle of July the land was planted to corn and aside from the necessity for considerable cultivation and hoeing during the first three or four weeks, the weed was very easily kept under control for the remainder of the summer. Since it was possible to cultivate the corn until quite late in the summer, most of the seedling plants that were brought in with the

Fig. 4.—Field E, May, 1916, showing type of cultivator and sweeps used.

Fig. 5.—Field E, June, 1916.

Fig. 6.—Field F, August, 1915.

Fig. 7.—Field F, October, 1916.

irrigating water were destroyed. After the corn got too large to cultivate, a very little hand hoeing removed all traces of Johnson grass.

FIELD F: INTENSIVE CULTIVATION, CORN AND COTTON

This field, having been mowed and burned over in the fall of 1915, was plowed in April the following year. Plowing, levelling and cultivating necessitated irrigations late in March, early in June, and early

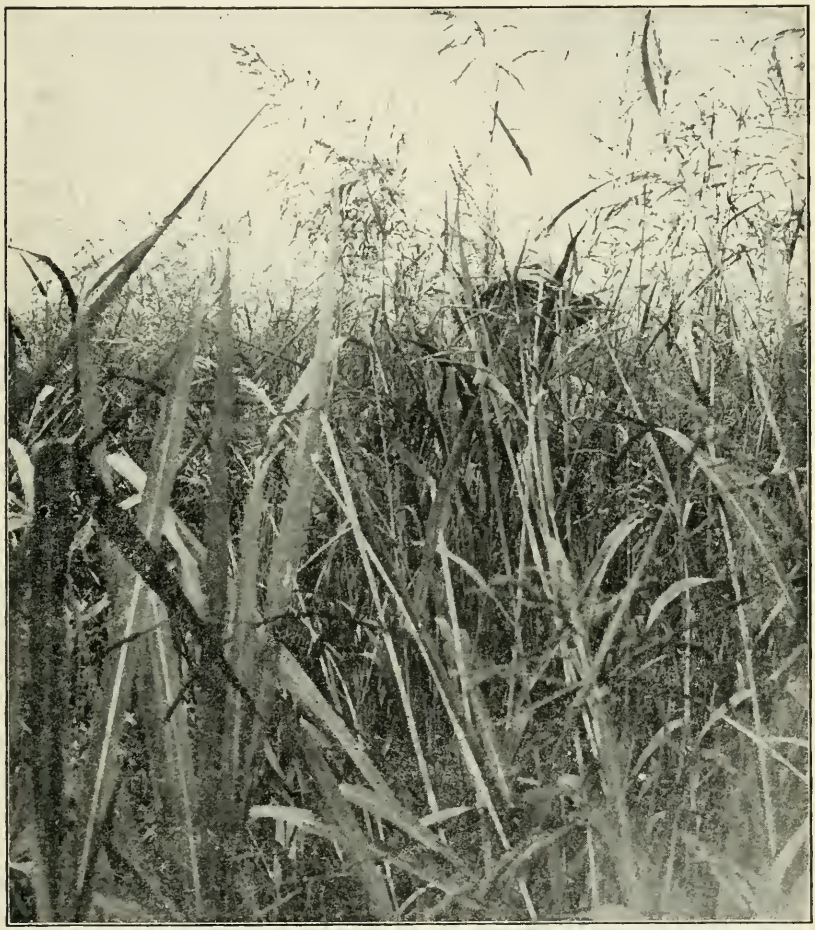


Fig. 8.—Johnson grass on Fields G and H, July, 1915.

in July. Since the land was held moist during this part of the season great numbers of Johnson grass plants came up, and in the absence of a suitable weeder, had to be kept in check by means of a cultivator. In the middle of July, 1916, corn was planted and for a short time consid-

erable cultivation and hoeing was necessary to hold back the Johnson grass. By late fall of that year, however, only seedling Johnson grass brought in by late summer irrigating water, was in evidence. In January and February, 1917, the land was plowed and a good deal of leveling done. This necessitated frequent irrigations, and the soil was at all times moist until after it had been planted to cotton in the middle of March. Very little Johnson grass emerged, however, and what did appear was easily controlled by means of the cultivator and by hoes.

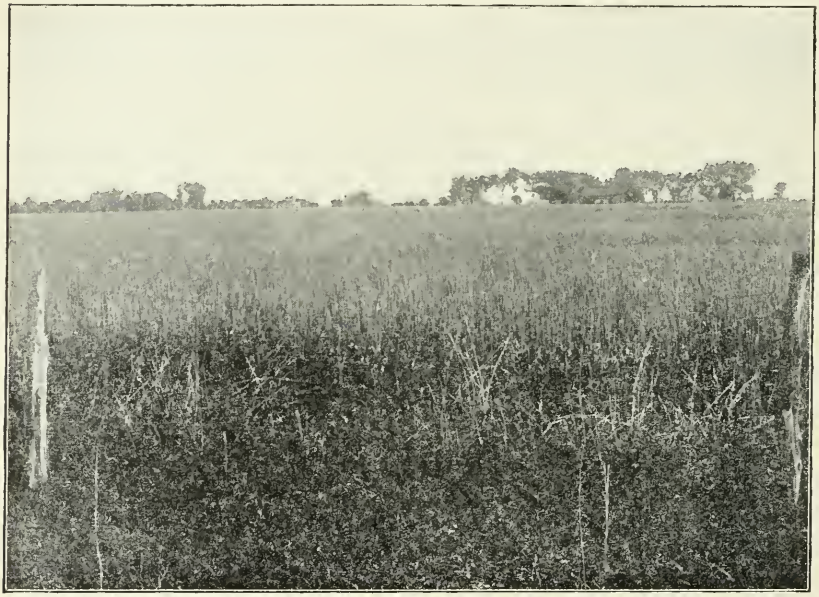


Fig. 9.—Wheat on Field G, May, 1916; no Johnson grass in sight.

FIELD G; SUMMER FALLOW, WINTER GRAIN

This 20-acre field was partially mowed and burned over in the fall of 1915. In March of the following year it was plowed dry. The Johnson grass soon came up again in abundance. The growth was kept in check by means of a weeder until August when the field was replowed. A three-inch rain early in September gave new life to the almost exhausted plants and for a time the weed was nearly out of control. In the middle of December the field was irrigated and sown to wheat. A very heavy stand and luxuriant growth of wheat held the Johnson grass in check until June, 1917, when the grain was harvested. The ground being very dry, the growth of weeds following the removal of the wheat was not rapid but by September

a considerable stand was noted and a large number of rootstocks were being formed. At this time the land was irrigated and deeply plowed. Shortage of labor and horse power prevented plowing immediately after the removal of the grain but if the land could have been worked at that time very much better results would have been obtained. As the field appears in the fall of 1917 the Johnson grass is under control but by no means eradicated.

FIELD H; CONTINUOUS DRY FALLOW

This field was partially mowed and burned over in 1915. In March and April, 1916, the land was plowed dry and the growth of Johnson grass visibly retarded. Leakage from an irrigating ditch and a heavy rain early in September encouraged the grass until it was very difficult to control with a weeder. By the fall of 1916, while a visible improvement had been made, the results obtained were far from what had been hoped for. Late in February, 1917, the field was disked and partial-

Fig. 10.—Field H, June, 1916; few Johnson grass plants appearing.

ly plowed, and during the remainder of the season a weeder was used quite frequently. In September the land was plowed dry preparatory to seeding to grains later in the year. At the present time, November, 1917, the growth of Johnson grass is not very noticeable although there

are many old rootstocks scattered through the field, and the summer rains have brought up a number of seedling plants.

Below is given a series of tables itemizing costs and returns from operations on the various fields.

Labor costs were high, from 25c to 30c per hour being paid for most of the work performed. Prices for crops produced were, however, also high, as much as $3.95 per cwt. being received for wheat, and as much as 79c per pound for Egyptian cotton.

TABLE I.—FIELD C, 40 ACRES; SUMMER FALLOW, WINTER GRAIN

Year	Crop	Plowing costs	Harrowing and disking costs	Other crop costs	Total costs	Cost per acre	Yield lbs.	Price per 100 lbs.	Total returns	Returns per acre
1915		$233.62	$ 10.25	.....	$ 243.87	$ 6.09	.....		.....	.....
1916		329.12	124.24	.....	453.36	11.33	.....		.....	.....
1917	Oats	.....	.....	963.07	963.07	24.07	32,201	$2.20	$ 708.41	.....
	barley	.....	.....	.....	.....	.....	350	$2.45	8.57	.....
	wheat	.....	.....	.....	.....	.....	64,661	3.95	2,554.10	.....
	gleanings	.....	.....	.....	.....	.....	6,775	2.50	169.37	.....
Grand total		$562.74	$134.49	$963.07	$1,660.30	$41.49	.....	.....	$3,440.45	$85.01

TABLE II.—FIELD D, 20 ACRES; SUMMER PASTURE, WINTER GRAIN

Year	Source of income	Plowing costs	Harrowing and disking costs	Other crop costs	Total costs	Cost per acre	Yield lbs.	Price per 100 lbs.	Total returns	Returns per acre
1915 and 1916	Barley	$150.62	$156.25	$510.47	$817.34	$40.87	36,977	$1.25	$462.21	$23.11
1917	Sheep								250.00	.....
	pasturage	.....	.....	.....	.....	.....	.....	.....	(est.)	12.50
	and barley	.....	.....	80.24	80.24	4.01	26,177	2.45	641.34	32.06
Grand total		$150.62	$156.25	$590.71	$897.58	$44.88	.....	.....	$1,353.55	$67.67

TABLE III.—FIELD E, 10 ACRES; INTENSIVE CULTIVATION, COTTON AND CORN

Year	Crop	Plowing costs	Harrowing and disking costs	Cultivating and hoeing costs	Other crop costs	Total costs	Cost per acre	Yield lbs.	Price per lb.	Total returns	Returns per acre
1916	Cotton	$131.50	$94.00	$282.00	$420.35	$ 927.85	$ 92.78	6,808 (seed cotton)	13.99c	$ 952.76	$ 95.27
1917	Corn	23.08	13.07	44.38	459.95	540.48	54.04	.....	.....	600.00 (est.)	60.00
Grand total		$154.58	$107.07	$326.38	$880.30	$1,468.33	$146.82	.....	.....	$1,552.76	$155.27

TABLE IV.—FIELD F, 10 ACRES; INTENSIVE CULTIVATION, CORN AND COTTON

Year	Crop	Plowing costs	Harrowing and disking costs	Cultivating and hoeing costs	Other crop costs	Total costs	Cost per acre	Yield lbs.	Price per lb.	Total returns	Returns per acre
1916	Corn	$60.75	$80.87	$128.24	$ 462.18	$ 732.04	$ 73.20	29,272 (in husk)	2.25	$ 660.00	$ 66.00
1917	Cotton	28.88	32.56	171.37	802.61	1,035.42	103.54	17,800 (seed cotton est.)	18.11c	3,225.00 (est.)	322.50
Grand total		$89.63	$113.43	$299.61	$1,264.79	$1,767.46	$176.74	.....	.....	$3,885.00	$388.50

TABLE V.—FIELD G, 20 ACRES; SUMMER FALLOW, WINTER GRAIN

Year	Crop	Plowing costs	Harrowing and disking costs	Cultivating and hoeing costs	Other crop costs	Total costs	Cost per acre	Yield lbs.	Price per 100 lbs.	Total returns	Returns per acre
1916	.....	$209.50	$ 91.87	$25.50	$238.14	$565.01	$28.25	.....	.....	.....	.....
1917	Wheat	81.58	15.12	.....	290.96	387.66	19.38	48,259	$3.95	$1,906.23	$95.31
Grand total	.....	$291.08	$106.99	$25.50	$529.10	$952.67	$47.63	.....	.....	$1,906.23	$95.31

TABLE VI.—FIELD H, 20 ACRES; CONTINUOUS DRY FALLOW

Year	Plowing costs	Harrowing and disking costs	Cultivating costs	Other costs	Total costs	Cost per acre	Returns per acre
1916	$207.75	$35.00	$37.62	$115.38	$395.75	$19.78	None
1917	56.53	30.39	$88.08	74.14	249.14	12.45	None
Grand total	$264.28	$65.39	$125.70	$189.52	$644.89	$32.23	None

TABLE VII.—SUMMARY OF COSTS AND RETURNS FROM JULY, 1915, TO NOVEMBER, 1917

Field	Size in acres	Total costs	Total returns	Gain	Gain per acre in two yrs.	Remarks
C Summer fallow winter grain.	40	$1,660.30	$3,440.45	$1,780.15	$44.50	Johnson grass entirely wiped out except for occasional seedlings from seed carried in irrigation water.
D Summer pasture, winter grain.	20	$897.58	$1,353.55	$455.97	$22.80	ditto
E Intensive cultivation, cotton and corn.	10	$1,468.33	$1,552.76	$84.43	$8.44	Very few rootstocks remaining and vitality of these seriously depleted.
F Intensive cultivation, corn and cotton.	10	$1,767.46	$3,885.00	$2,117.54	$211.75	Johnson grass entirely destroyed except for very few seedling plants from seed carried by irrigating water.
G Summer fallow, winter grain.	20	$952.67	$1,906.23	$953.56	$47.67	Johnson grass well under control but with a considerable number of vigorous rootstocks scattered through the field. With carefully conducted operations on this field Johnson grass will soon be wiped out, but if neglected will be as bad as ever in one season.
H Continuous dry fallow.	20	$644.89	.....	.....	-$32.24* *Loss	Few remaining rootstocks scattered uniformly over field but with vitality seriously diminished.

INTERPRETATION OF RESULTS

In figuring gain or loss in the above tables actual profits were not reckoned since no charge was made for interest on investments, depreciation of implements, etc., taxes, and shares of general supervision costs which should be divided among the fields. Accordingly, actual losses were sustained both by fields E and H and actual profits were materially lower on the other fields than figures represented as gain indicate.

Field C: The hardest blow given to Johnson grass on Field C was the dry plowing of August, 1915. Leaving this ground rough throughout the succeeding winter also assisted materially. The plowing in April of 1916 made the remainder of the fight easy. In addition, actual profits were swelled materially by the abnormally high prices of grain in 1917.

Field D: In spite of the fact that this field did not return a great deal of profit we are led to favor the control of Johnson grass by means of close pasturage. Much greater profits should be realized when such a field is allowed to grow grain in winter and when hogs are turned in to feed upon the rootstocks turned up by plowing. A combination of winter grains and pasturing with both sheep and hogs in the summer is one of the most practicable methods of quickly and surely bringing Johnson grass into subjection.

Fields E and F: The results from Field E appear to be inconsistent with those of Field F. The only difference in treatment of the fields has been the planting of cotton in Field E in 1916 followed by corn the succeeding year, and the reversal of this rotation in Field F. However similar the treatment may appear to have been there is a material advantage in following corn with cotton for the following reasons: Since corn is not usually planted until late in June or early in July, the most rapid growth of the Johnson grass, which takes place earlier in the season, may be combated by clean cultivation with weeders and results can be obtained more cheaply than with row cultivators and hand hoes. If this early cultivation is carefully done the Johnson grass will be fairly under control by corn planting time and the work necessary to keep it in subjection is much less than that demanded earlier in the season. Furthermore, corn can be cultivated later than cotton, and even after it is too large to cultivate with horses the few remaining Johnson grass plants can be easily handled with hoes. In this way plants from seed brought in by the irrigating water of late summer may be destroyed before they have reached the stage where the rootstocks are formed. This makes the fight against Johnson grass much

easier the next year when cotton is planted. If cotton is used first the Johnson grass must be fought the hardest at a time when the young cotton plants must be handled with greatest care; and while the old rootstocks of Johnson grass can be brought under control, the growing cotton interferes with late cultivations that should destroy seedling plants from seed brought in by late summer irrigations. Many of these seedling plants by fall form quite large and vigorous rootstocks. This necessitates a great deal of work the following spring before the planting of the next year's crop of corn. If a green manuring crop is planted on this land prior to putting it in corn a very troublesome growth of Johnson grass will appear before the crop is large enough to be of material advantage to the ground. Thus in Field E, in 1917, a crop of tepary beans had to be turned under before their value as a green manure had paid for the expense of planting them. The financial returns from Field F have been materially increased over those from Field E by virtue of the fact that the prices of cotton in 1917 were almost double the prices for 1916, which also were abnormally high; while the prices of corn did not change correspondingly. On account of conditions not regulated by the experiment we secured in 1917 double the yield of cotton obtained in 1916.

Field G: When land is held fallow in summer and seeded to small grains in winter, ample time is available to put the seed bed in perfect shape, and on such land a very high yield of grain may be obtained. Yields of 45 to 50 bushels of wheat per acre, and the abnormally high prices of grains in 1917, left considerable profit from the treatment of Field G. Shortage of labor at critical times and the thorough wetting of the land by a 3-inch rain in early September, 1916, materially reduced the efficiency of our Johnson grass control work on this field. Lack of plowing facilities immediately after the removal of the 1917 grain crop, allowed further opportunity for the recuperation of Johnson grass. As a result, the land is still quite badly infested though not so seriously as to make it particularly difficult to control. If it had been possible for us to conduct all our cultural operations on this field as soon as the need was manifest, there is no question that the Johnson grass would have been almost completely destroyed.

Field H: Continuous dry fallow is very effective and does not demand a very great expenditure of labor; but the danger that a heavy rain will undo a good deal that has already been accomplished and the loss of the use of the land makes this method impracticable. While continuous fallow does not demand a great deal of labor it sometimes requires considerable work in a very short time, usually at a season when other parts of the farm require attention.

SUMMARY AND CONCLUSIONS

Plowing dry in midsummer is slow, expensive and very hard on horseflesh, yet it is much more effective than plowing when the ground is moist or at other seasons of the year. Costs of dry plowing in summer with horses have run as high as seven dollars per acre in the work described above and usually are not less than four and one-half dollars per acre. Deep plowing in midsummer when the land is very dry can best be accomplished by means of tractors.

The quickest way to rid land of Johnson grass is to overgraze with sheep, meanwhile irrigating frequently. The most effective way, as well as the most economical, is the frequent cultivation of a late summer crop, such as corn, followed by another crop demanding much tillage, such as cotton. The exact crops to be chosen should depend upon the market outlook and the probable price which can be realized. The method demanding the least labor and outlay of cash is dry fallow in summer followed by winter grains. This system may be very profitable when grain prices are high.

It is rarely feasible to attempt to rid a place of Johnson grass by following one method alone; but a combination of methods which properly distributes the labor, keeps up the fertility of the soil, and returns a steady income, should be adopted.

To control Johnson grass successfully provision must be made for carrying on the desired operations as soon as the need is manifest. A delay of one week may overcome the good effects of several weeks of careful and consistent work.

A method including dry fallow is reasonably effective and economical, but a heavy rain or an accidental leakage of irrigation water may undo a great deal of work.

If Johnson grass is to be eradicated by grazing with sheep more animals must be pastured than the land will satisfactorily maintain, and additional feed must be supplied since the effectiveness of this method depends upon the grass being grazed as closely as possible. Furthermore, the growth of the Johnson grass must be encouraged in every feasible way, particularly by supplying plenty of moisture, in order to more quickly exhaust the stored up food in the rootstocks.

When Johnson grass is to be killed by the tillage of ordinary farm crops some provision must be made to take care of the seed which is brought in by irrigating water during late summer. In the absence of a suitable seed trap or screen, hand hoeing is usually necessary. Johnson grass does not form a rootstock until about the boot stage, which is the time the head is appearing from its enclosing sheath. Prior to

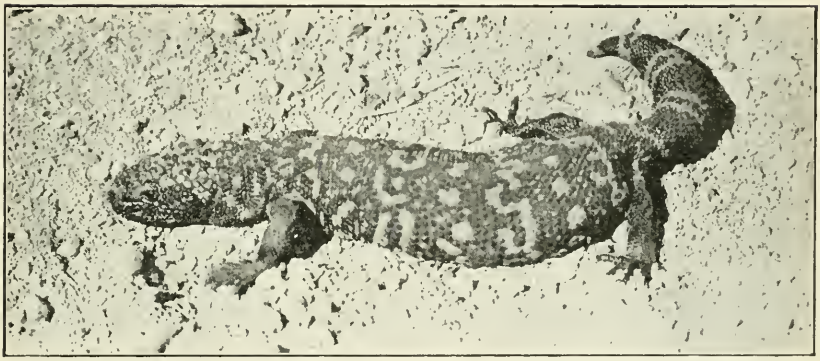
this time a Johnson grass plant is killed by any operation which severs it beneath the surface of the ground. Therefore, it is especially desirable to destroy it before the rootstock is formed.

University of Arizona

College of Agriculture

Agricultural Experiment Station

Bulletin No. 83



Gila Monster. Photograph from life. About one-fifth natural size.

Poisonous Animals of the Desert

By Charles T. Vorhies

Tucson, Arizona, December 20, 1917

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AGRICULTURAL EXPERIMENT STATION

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The Experiment Station offices and laboratories are located in the University Buildings at Tucson. The new Experiment Station Farm is situated one mile west of Mesa, Arizona. The date palm orchards are three miles south of Tempe (cooperative, U. S. D. A.), and one mile southwest of Yuma, Arizona, respectively. The experimental dry-farms are near Cochise and Prescott, Arizona.

Visitors are cordially invited, and correspondence receives careful attention.

The Bulletins, Timely Hints, and Reports of this Station will be sent free to all who apply. Kindly notify us of errors or changes in address, and send in the names of persons who may find our publications useful.

Address, The Experiment Station,
Tucson, Arizona.

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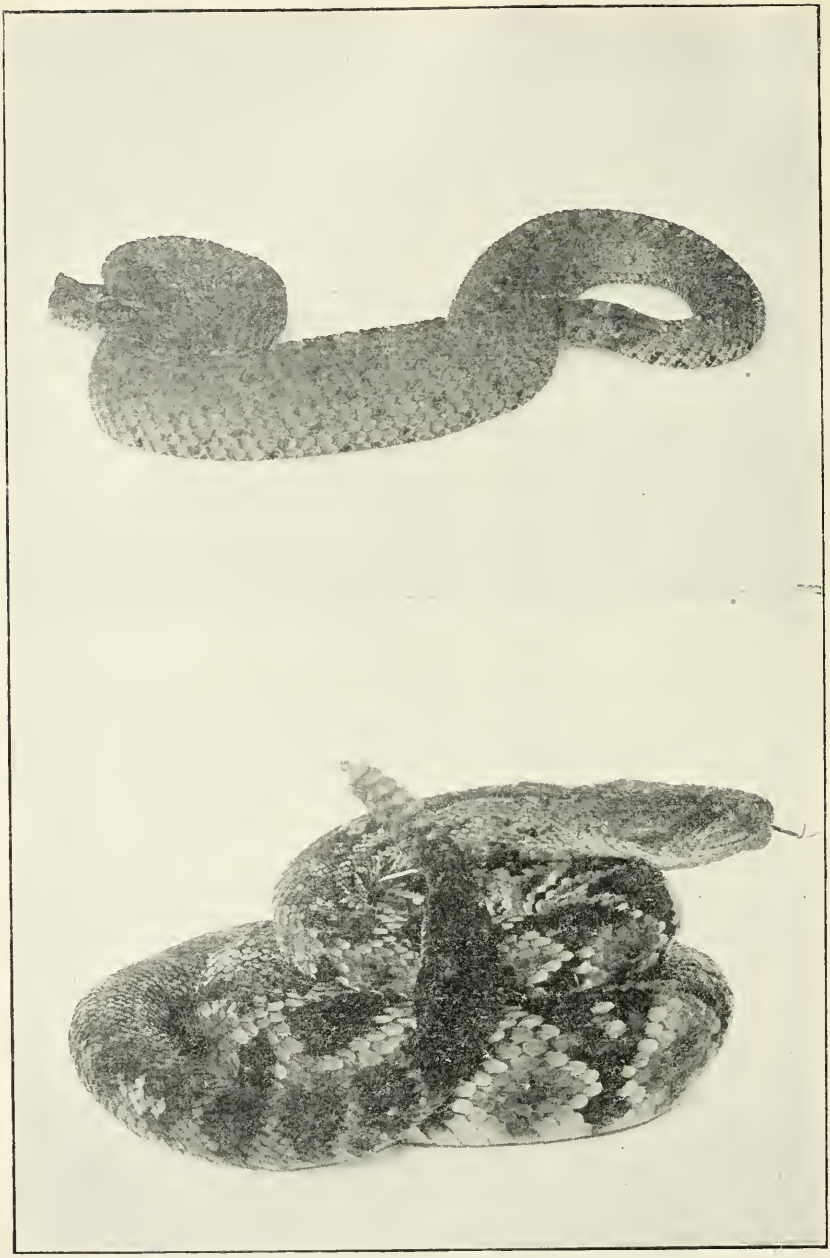

Plate 1.—Upper, Horned Rattlesnake, or "sidewinder." (*Crotalus cerastes*). Lower, Black-tailed Rattlesnake. (*Crotalus molossus*). Photographs by Dr. J. Van Denburgh, California Academy of Sciences, San Francisco, Cal.

Poisonous Animals of the Desert

By Charles T. Vorhies

INTRODUCTION

The arid and semi-arid southwestern area of the United States, with its warm climate, is the habitat of a considerable number of animal species which are more or less objects of dread for the average person. Some of these are justly feared, but many are not nearly so dangerous as popular story and belief would have them, while still others are quite harmless. A considerable part of Arizona's fauna is native to more tropical Mexico, but it also has many species of a somewhat wider distribution from north and east, and this commingling of faunas gives it perhaps as large a variety of these undesirables as any state in the Union. In addition, there seems to be an unusual amount of baseless prejudice and superstition concerning many totally harmless forms, due possibly to the large element of Mexican population. Certain superstitions, for example, concerning the "campamocha" are traceable to this source.

The purpose of this bulletin is to offer authentic information regarding a number of these more or less poisonous species and their relative degrees of "frightfulness," and to make it possible for the reader to distinguish between fact and fable; to enable him to keep cool when in no real danger; and even to enable him to distinguish the "business end" of some of these, for there exists great confusion as to whether a given form bites or stings. More than one intelligent person does not distinguish between the head and the tail ends of a common centipede.

While it would serve no useful purpose to give a full list of original papers on the animals with which this bulletin is concerned, we wish to give credit and reference to a few recent authoritative texts which have been freely consulted and used.* These works will hereinafter be referred to simply by use of the names of the authors.

* 1. The Spider Book, by J. H. Comstock. Doubleday, Page & Co.
2. Medical and Veterinary Entomology, by W. B. Herms. The MacMillan Company.
3. Handbook of Medical Entomology, by Riley and Johannsen. Comstock Publishing Company.
4. The Reptile Book, by R. L. Ditmars. Doubleday, Page & Co.

VERTEBRATES

First in importance of the animals to be considered herein are the poisonous reptiles,—the snakes and the Gila Monster. When poisonous snakes are mentioned, the average person in the Southwest will think at once of rattlesnakes, and probably only of rattlesnakes, and we shall see that there is considerable justification in fact for this. Rattlesnakes or "rattlers" are distinguished from all other snakes on the globe by the possession of a peculiar appendage, the rattle. This rattle, by the way, does *not* at all accurately indicate the age of its bearer. Careful observation shows that each shedding of the skin results in the formation of a new section of the rattle, and that as many as three or four sheddings may occur in a year. Division of the number of segments of a complete, unbroken rattle by three will give more nearly the true age of the reptile.

SNAKES

Rattlesnakes are found only in the New World, mainly in North America above Panama, and more in the southwestern United States than elsewhere. Hence Arizona is practically the center of the chief rattlesnake inhabited area of the world. To put this in another way, nineteen species of rattlers are known. Only one of these is found south of Central America. Of the other nineteen kinds, fourteen occur in the United States, and of these Arizona has within its borders, according to the available data, eleven. It is hardly within the main purpose of this bulletin to discuss the different kinds in detail, yet doubtless the reader will be interested in a brief resume of the kinds, sizes, and relative abundance of these species, as well as suggestions as to their probable distribution in the State.

All rattlesnakes are divided into two principal groups: the Pygmy rattlesnakes (*Sistrurus*), and the larger rattlesnakes (*Crotalus*). As the name indicates the Pygmy rattlesnakes are of small size, seldom as much as a yard in length, and the rattles are small. There are more kinds of the larger rattlesnakes than of the Pygmy rattlesnakes, and since they are usually larger they are better known. (Certain details of structure enable the specialist to distinguish between them regardless of size.) Only one variety of the Pygmy rattlesnakes is known to occur in Arizona, Edward's Massasauga, (*Sistrurus catenatus edwardsii.*) This is one of the largest of its group, attaining occasionally to a yard or even more

in length, and its range extends into southern Arizona from the eastward to about the central part of the State.

Our larger rattlesnake species are as follows:

The Western Diamond Rattlesnake (*Crotalus atrox*), next to the largest of all, attains to a length of seven feet, and is common in at least the southern half of Arizona. Distinguished by *the white tail, banded with jet black.* A variety of this, known as the Mountain Diamond Rattlesnake, is found at higher elevations, the typical form being found in the desert valleys. For the first of these the common name of Desert Diamond Rattlesnake has also been proposed, and the latter seems slightly more appropriate, since it is the common form in the desert valleys.

The Black-Tailed Rattlesnake (*Crotalus molossus*), may attain to as much as four or five feet in length. It is reported common in northern Mexico and extreme southern Arizona, though two were once taken on San Francisco Mountain, near Flagstaff. It is found in the mountains rather than in the desert, the largest examined by Ditmars having come from "the mountains near Tucson, Arizona," and was reported by the late Mr. Herbert Brown to be "fairly common in the Santa Catalina and Pincon Mountains."

The White Rattlesnake (*Crotalus mitchellii*), as its name indicates, is very light in color, even so white as to have suggested to one collector when coiled the appearance of bunches of cotton. About three and one-half feet seems to be the maximum length. This is probably restricted in Arizona to the southwestern portion and records do not indicate that it is very common anywhere. The tail being white with black rings might lead to the assumption of its being a very light variant of the Diamond Rattlesnake. Two bright red specimens have been reported from Cave Creek, Maricopa County.

Price's Rattlesnake (*Crotalus pricei*), is next to the smallest of the *Crotalus* kinds, an adult measuring a little less than two feet in length. It is rare, at least in the United States, Ditmars reporting that "barely a dozen specimens have been taken" in this country. It was discovered in the Huachuca Mountains in 1895. It ranges probably only in the most southern portion of Arizona, at considerable elevations in the mountains.

The Green Rattlesnake (*Crotalus lepidus*), is the smallest of the *Crotalus* species, less than two feet in length, slender, with broad head. Color "greenish-gray, or rich dark green above, crossed at intervals with narrow, jet-black bands. The bands are

usually bordered with pale greenish-yellow. The abdomen is pinkish, or yellowish-white." (Ditmars). This is a rare rattlesnake, found thus far only along the Mexican boundary in Mexico, Texas, New Mexico and Arizona.

Our chief purpose in giving these details, particularly with regard to the last two species, is in the hope that specimens may be sent to our museum from loyal Arizonians. We, for that matter, would be pleased to receive good specimens of any of the rattlesnakes found in Arizona, of which we have at present only a meager collection.

The Tiger Rattlesnake (*Crotalus tigris*), is upward of four feet in length, strongly banded on the posterior two-thirds of the body with yellowish-gray and very dark bands. It is found chiefly in barren mountains of the extreme Southwest, i. e., southwestern Arizona and southern California, and was reported common near Yuma in the flood season of 1905.

The Horned Rattlesnake (*Crotalus cerastes*), is a small but distinctive species with a small horn-like protuberance over each eye. It is well-known by reputation in Arizona, and best known as the "side-winder." The latter name is given to it because of the fact that when hurried it moves by a peculiar looping movement which carries it obliquely sidewise as well as forward, an adaptation to progression over yielding sand. The side-winder is small, two to two and a half feet in length, and is probably found in all desert areas of Arizona, since it is known also in Utah, California and Nevada. It has the reputation of being a very dangerous reptile, due perhaps to agility and a vicious temperament. It is not likely that its poison is different in quality or quantity from that of other rattlers.

The Pacific Rattlesnake (*Crotalus oregonus*), is called the Black Rattlesnake where known in Arizona. Ditmars does not include Arizona in its range, but Dr. J. Van Denburgh of the California Academy of Sciences has secured three specimens; one from Oak Creek, Coconino County; one from Cave Creek, Maricopa County, and one from the Santa Catalina range. Dr. R. H. Forbes, of the Experiment Station, also assures me that he has seen the Black Rattlesnake in the latter mountains. In coloration the Santa Catalina specimens appear much darker than the one figured by Ditmars. This kind reaches a length of about three feet.

The Prairie Rattlesnake (*Crotalus confluentus*), is not included with Arizona's rattlers by Ditmars, and again we are indebted to

Dr. Van Denburgh for a single specific record, he having photographed a specimen from Cave Creek. While usually only of moderate size, specimens up to six feet in length are on record. This is the common rattler in the great plains region between the Rocky Mountain divide and the Mississippi River, but is probably not common anywhere in Arizona, unless it be in the northeastern portion of the State.

Another species, more recently described, (*Crotalus willardi*) is represented in the University collections by a single specimen. This was taken in the Santa Rita Mountains, May 28, 1912, at about 7500 feet altitude. It is hardly more than 16 inches in length, with small rattles. The back is marked with two rows of small, irregular, somewhat star-like dark spots. No further data are at hand concerning this kind.

Now, *all* rattlesnakes are venomous and *dangerous, deadly,*— let there be no mistake about that. Familiarity occasionally breeds contempt, even here, and some foolhardy individuals with better luck than sense, handle rattlers. Such, too, have been known to pay the penalty eventually for their foolishness. The white man had best leave the barehanded manipulation of live rattlers to the Hopi snake priests, who are seemingly much wiser than we in the matter of remedies.

The rattlesnake strikes,—literally stabs,— with fangs pointing toward the victim, and it momentarily compresses the jaws (bites) at the instant of penetration of the fangs, voluntarily injecting the venom through the hypodermic needle-like fangs by definite muscular action. There is thus no matter of chance about the placing of the poison in the wound. Removal of the fangs renders a rattler comparatively harmless for only a few days at most, since a series of new fangs is constantly moving forward from behind to replace the old as they are lost. Even immediately after removal there is danger, for the poison is ejected from the glands as well without as with the fangs and may enter the wounds made by the smaller teeth. Though there is necessity for proper precaution in the vicinity of a rattlesnake, there is no need to be panic-stricken at the mere sight of one. The snake cannot strike accurately for much more than half its length,—not its whole length in any case, and absolutely cannot *leap* at an intended victim.

The writer has been assured by a prominent physician, long resident in Tucson, that he has never seen a serious case of rattlesnake bite at the time he would like to see it, *viz.,* immediately after

the injury, and he further explained that this was because the serious cases seldom reach the physician. Cases in which the fangs have not struck fairly or but glancingly, or through clothing, come in for treatment. From all that the writer can glean from authoritative sources he believes the above to be correct, since it is doubtless true that not only is the great majority of the Mexican population ignorant of the proper treatment for rattlesnake bite, but also that much of the white population is equally so. The principal object of offering information on poisonous snakes in this publication is then to emphasize the proper method of dealing with this emergency, and no less to combat the common, but wrong, method of treatment.

First of all, notwithstanding a firm rooted popular conviction to the contrary, *whiskey is not a remedy*. It is not only useless, but absolutely harmful, especially if given in large quantities, as is the usual tendency. If you want to finish the job begun by the rattler, take plenty of strong alcoholic stimulant. Small doses at the proper time *may* be of service. The facts as to whiskey treatment may be reassuring only to some persons who find themselves in a rattlesnake country where bottled "snake-bite" is taboo.

If one would be prepared to deal properly with snake bite let him carry when in the open at least the following equipment, which should be on the person to be effective, not half a dozen miles away in camp, cabin or auto.

1. A very sharp knife or razor. Best, because it is least bulky and can be kept clean, is a good safety razor blade. This could easily be carried sterilized in a waxed paper wrapping.
2. A small vial of crystals of potassium permanganate.
3. A rubber band, of sufficient size and strength to be used as a ligature without the delay of tearing strips of cloth, tying knots, twisting, etc.

These are the most important—the essential—things. Absorbent cotton, sterilized gauze, and some one of several antiseptic solutions are next in usefulness. A hypodermic syringe and strychnine tablets may be valuable for those who understand their use, but if the other things are near at hand at the moment needed, these are not so likely to be wanted.

Now for the procedure to be followed in the event of being bitten:

1. KEEP COOL, life depends on it.
2. Place a ligature above the wound *at once*. If bitten on a finger, ligature only the finger. If on hand or arm,

or on foot or shank, place the ligature above the elbow or knee, where there is but one bone in the limb. If the rubber band is on hand much time will be saved for the next step. If not, apply a ligature (tourniquet) of cloth and twist it sufficiently to cut off circulation in the limb. Do not leave a ligature in place for more than twenty minutes, or thirty at the very outside, lest mortification of the limb begin.

3. As quickly as possible after being struck, but only after applying the ligature, cut across the fang punctures for about one inch, both ways, *deeper* than the fangs penetrated. If bitten on the finger, cut to the bone at least lengthwise. Look out for tendons in a cross-cut on the finger.
4. Bleed the wound as thoroughly and rapidly as possible. If sucking the wound aids bleeding, *suck it.*
5. After some good bleeding wash the wound *thoroughly* with potassium permanganate,—enough in water to produce a deep wine color. If without water, as might well be the case in the desert country, rub some crystals into the wound, aiding their solution with saliva. This chemical specifically destroys all the venom with which it comes in contact. There are other substances which will do this, but their action on the flesh is more injurious. If you have water, use it, as the use of crystals is rather more likely to injure the flesh than the use of solution.
6. Remove ligature.
7. At this point *small doses* of whiskey as a stimulant may be useful. Hypodermic doses of strychnine act as a powerful stimulant and may be used by those properly equipped if fainting spells indicate a need of such.

While the above procedure is being carried out send for a physician or start to one at the earliest possible moment. The wounds made in the drainage process should be dressed as carefully as circumstances permit, using for this purpose the surgical dressings and antiseptic solution for a wet dressing, if at hand. If these are not available keep the wound as clean as possible until a physician can be had to apply proper dressings. In any case have a physician care for the wounds, for the deadening effect of the poison on the natural defenses of the blood makes the part extremely liable to germ infection, such as blood poisoning. Since the permanganate can only act against the poison with which it comes in direct contact, *it is useless after the venom has become disseminated in the blood.* Hence the importance of immediate action for beneficial results.

Besides the rattlesnakes there are not more than two other poisonous species of snakes in Arizona. One of these is known as the

Annulated Snake (*Sibon septentrionalis*) and has been reported from the southern part of the State. It is probably not at all common. It is rather slender, about two and a half feet long, and its poison fangs are in the back of the mouth, hence they do not injure by striking. If provoked into seizing a finger so as to imbed the fangs the results would be severe, though perhaps not fatal. Ditmars calls it "dangerous, but not deadly."

The only other poisonous snake to be found here is the brilliantly colored Sonoran Coral Snake (*Elaps euryxanthus*). This slender little snake, seldom above two feet in length and often shorter, is found in central and southern Arizona. It is marked with black, yellow, and red bands *encircling* the body, the *black always bordered on both sides by the yellow.* This snake is dangerous if given a good opportunity, though on account of its small size it is hardly dangerous save when stepped on barefoot or handled, the latter being sometimes done under the impression that it is a harmless snake. Relatively to its size its fangs are as long as those of some other exceedingly dangerous snakes, but actually they are not large enough to penetrate a fair covering of clothing. It seizes without warning and *chews* to imbed the fangs, but does not strike as does the rattlesnake and is said never to bite save when actually touched. Its poison, however, is more virulent, drop for drop, than that of the rattlesnake. Deaths from the bites of larger species of the same genus (*Elaps*) often occur in South America, and it is related to some of the most deadly snakes known. Its small size and resemblance to certain harmless snakes has led to an underrating of its true character.

Note the following distinctions:

Black-yellow-red-yellow-black, Coral Snake.
Yellow always *between* black and red.
Red-black-yellow-black-red, harmless King and Milk Snakes.
Black always *between* red and yellow.

Since potassium permanganate is a specific destroyer of all snake venoms, treatment for a bite of the Coral Snake or other poisonous species would be the same as for rattlesnake bites. It may be stated *most emphatically* in this connection that the popular impressions regarding easy distinctions between poisonous and non-poisonous snakes, such as the large, angular head like that of a rattlesnake for poisonous species, and the small rounded head for harmless species; or brilliant colors as in the king and milk snakes for harmless species, *do not hold.* The Coral Snake alone violates

both these rules, and there are harmless snakes with enlarged heads, and several poisonous snakes with heads like those supposed to belong to harmless kinds. The best rule we can suggest is that you learn to know the poisonous snakes of your region, for they are few to learn; then regard all others not merely as harmless, but as *actually useful*, and treat them accordingly. Of all American species of snakes, only 17 are poisonous. While it is true that the venomous snakes are very useful also, we shall not plead for them, but certainly there is not the slightest basis in fact for doing aught else than protect the non-poisonous. This is so important at any time, and particularly now, when every agency affecting our crops is being carefully reckoned with, that we will take time and space to quote from an article by Mr. G. K. Norton, in *American Forestry*, who puts the case convincingly. He says, after recounting the facts concerning the millions of dollars of damage done by rodent pests:

"Reptiles are a very important factor in the natural work of restraining the too rapid increase of rodents. Practically all our snakes feed largely upon rodents. One in particular which has a wide range is the *Lampropeltis doliatus triangulus* (milk snake, house snake, spotted adder, checkered adder), which finds 90 per cent. of its diet in small mammals. This reptile, together with dozens of others, is absolutely harmless, defenseless, and in no way destructive, though many ridiculous tales are told of it.

"The gross ignorance regarding our snakes causes slaughter of all things that wear scales and crawl. Farmers should protect and breed the harmless snakes rather than kill them. Many European countries have protective legislation. Another fact: all the king snakes—and the family is large—are natural enemies of other snakes and eat many of them. In numbers they probably overbalance the poisonous species and by general distribution usually occupy the same habitat as the dangerous snakes. In this way they materially help to lessen danger of poisonous snake-bite. Until a person is able to distinguish and name a snake immediately, and know whether it is dangerous or not, that person has no right to kill any snake. Every time a snake is killed more damage is being done than good."

LIZARDS

Just one other poisonous reptile belongs to our fauna,— the Gila Monster (*Heloderma suspectum*, cover cut.) This and a closely related species, *Heloderma horridum*, found only in Mexico, are the *only poisonous lizards in the world*. Absolutely no other lizards (these including the so-called "horned toads") are poison-

ous. The Gila Monster has poison glands, but in the lower instead of the upper jaw, the secretion oozing out between the teeth and the lower lips. It has no poison fangs, however, and therefore no definite mechanism for forcibly injecting poison with a stroke as does the rattlesnake. It will snap and bite if irritated, and will cling like a bulldog when it gets hold, and poison may enter the wounds made by its numerous small sharp teeth as a result of the tenacious grip of the animal. The effects of its bite are variable, owing doubtless to the imperfect application of the venomous saliva. Though some reports have it that human deaths have resulted from the bite of this animal, these reports are but hearsay and fade away to nothing upon investigation. The writer is indebted to a reputable physician of Tucson who has made considerable effort to authenticate a single case of death caused by the Gila Monster, and has failed to do so. An exhaustive report on "The Venom of *Heloderma*," by Leo Loeb, published by the Carnegie Institution, as well as the researches of other investigators, shows that the venom produces fatal results in various small animals, such as rats, mice, frogs, guinea pigs, etc. As to effects on man, we find no local data to discountenance the following statement from Loeb's report:

"No death of a human being has come to our knowledge that can be attributed to the bite of a Gila Monster. A bite from this animal is in man either followed by no symptoms at all or by a local swelling, perhaps extending to the shoulder, if the bite affected the upper extremity. * * * * * * In all the reports concerning the local effect of the bite of the *Heloderma* in man, mention is made of the rapid appearance of swelling and hemorrhagic discoloration of the skin at the site of injury. We found that when fresh venom was injected subcutaneously into an animal, no swelling or hemorrhage appeared at the site of injection; and when venom was injected intramuscularly, no hemorrhage was noted. * * * * * It is impossible, however, to absolutely rule out mechanical injury as a factor in causing the appearance of these local symptoms when an individual is bitten by a *Heloderma*. The animal has very powerful jaws and its bite would easily bruise a large area of flesh and skin. When the animal bites it clings tenaciously, and in endeavoring to extricate a wounded part the injury might easily be increased."

Whether potassium permanganate is destructive to *Heloderma* venom is not determined. Therefore we cannot recommend it as of value in case of a bite by this animal. We would only suggest releasing the bitten part as rapidly and yet as coolly and carefully as possible and then seeking a physician, perhaps first inducing

some bleeding and then washing the wound with an antiseptic. The venom is not to be regarded as deadly to man, hence there is no need for hysterical fear.

In closing on *Heloderma* we would suggest that there is no good reason for remorselessly slaying every Gila Monster encountered. Rather should we class it with the road runner and the peccary as unique features of our fauna, a part of the characteristic landscape of Arizona, like the giant cactus among the flora of the State.

We have already said that all other lizards are non-poisonous, yet the majority are more or less feared by many people. Of these,

Fig. 1.—Banded Gecko (*Eublepharis variegatus*). Harmless.

if there be any one kind deserving mention here as perhaps more often feared by those who meet with it than are the general run of lizards, that one is the delicate, retiring, absolutely harmless, little lizard known as the Banded Gecko (Fig. 1). It is feared because it is mistaken for a "young Gila Monster," this being in part due, possibly, to the light-yellow and dark bands, which, however, are much more regular than on the Gila Monster; and to the fact that its small soft scales have somewhat the rounded, bead-like shape of those of the larger animal. (This is assuming that the frightened person looks closely enough to see the scales, which is doubtful.) The Gecko does not hiss, but produces an audible squeak. It is probably mainly nocturnal in habit. Ditmars gives the length as three inches, but the specimen from which our figure was taken is four and three-quarters inches long.

SKUNKS

Keeping strictly within the limits of our subject, we would not deal with any mammals, for we have none which are poisonous in the proper sense of the term, as used elsewhere in this publication. But inquiries having come regarding the so-called "hydrophobia skunk," it should be treated in this connection.

Probably none of the many animals suspected of being dangerous in Arizona has created so wide a diversity of opinion as has this one. In one sense perhaps, a myth, this animal is nevertheless much feared in a considerable portion of the Southwest; yet the "tenderfoot" is moved to much mirth at the suggestion that the skunk will boldly bite a person sleeping out unprotected. The writer has laughed at many detailed stories of the hydrophobia skunk, and notwithstanding the circumstantial tales has often slept unprotected on the ground.

It is most unwise, however, to dismiss such a universally feared animal without investigating carefully all available data on the matter. Though we shall find that there is no basis for the widespread fear of some animals discussed herein, we desire to stand on facts in any case. I should be the last to deny that a skunk bite might produce hydrophobia, for we know that a wide variety of animals are subject to the disease and can pass it on through the saliva, probably all of the cat and dog tribe, as well as others in this category. The feature of this instance is that there is popularly supposed to be a particular species or kind of skunk whose bite *always* gives hydrophobia. If this be true, then the skunk assuredly differs from any of the other animals which are subject to rabies; for in other cases, as the dog, an individual animal gets the infection from some other infected animal (never spontaneously from heat or thirst), suffers from the disease, and while so suffering is capable of conveying the infection to other animals. Rabies (hydrophobia) is a germ disease and can no more be contracted spontaneously than can typhoid fever, or tuberculosis. It is the idea carried with the term "the hydrophobic skunk," rather than the idea that some skunks might be suffering from the disease and therefore dangerous that throws the proposition into disrepute with so many people; and in addition to that, perhaps, the very details as usually given, instead of carrying conviction, seem merely to be the embellishments of the joker trying to "stuff" the newcomer.

When we look for information on skunks in systematic works,

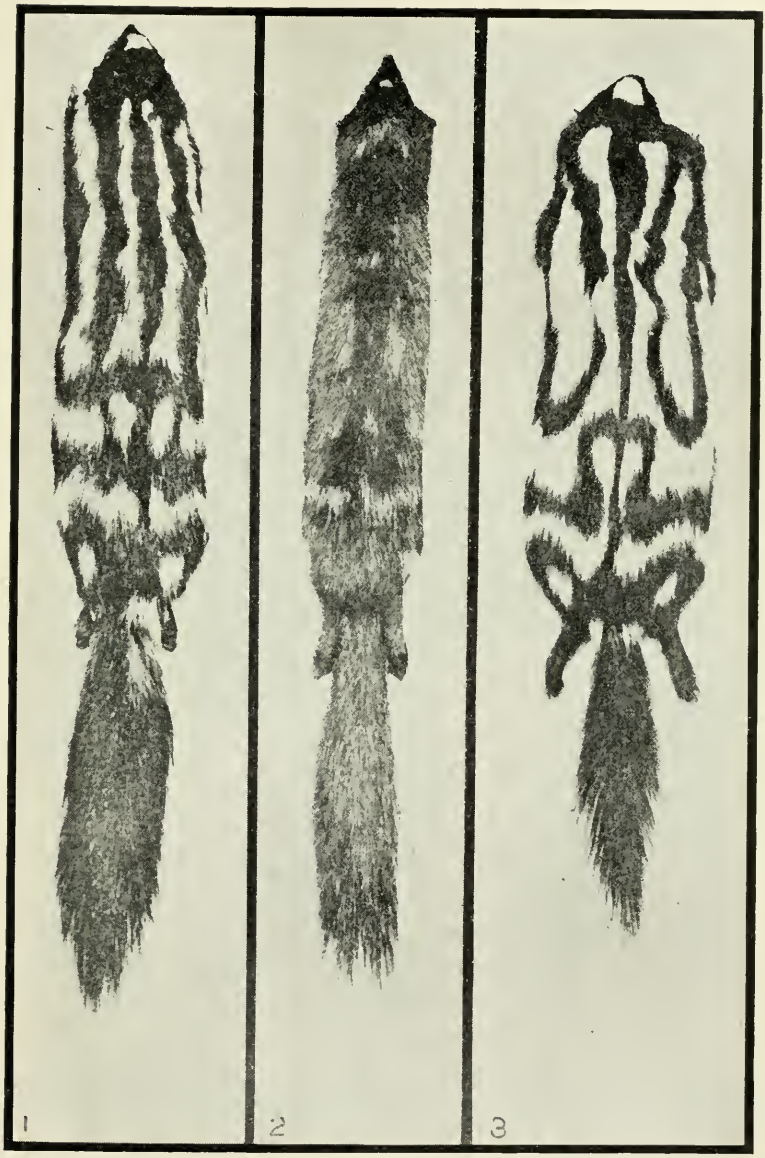

Plate II.—Skins of spotted skunks, (*Spilogale*). No. 3 is a species found in Arizona. (From N. American Fauna, No. 26.)

we find first that all of the species fall into two commonly known groups (genera). The larger skunks (*Chincha* or *Mephitis*) are marked with a stripe or stripes down the back, except a few individuals which are wholly black. They are never spotted. The smaller skunks (*Spilogale*) are spotted in addition to whatever stripes they may have, or striped and cross-banded so as to appear more or less spotted, and are often known as spotted skunks or "civet cats." (These, by the way, are properly called civet, though in Arizona the Ring Tail is miscalled by this name.) Plates II and III indicate clearly the differences between striped and spotted skunks (North American Fauna No. 26) we are told that "while there are a few authentic cases of skunk bite having resulted fatally, there are also many instances in which it has produced no ill effect whatever. The recorded cases of skunk rabies are nearly all from the plains region of the west * * * * and relate more to *Mephitis* than to *Spilogale*. The most plausible explanation of these facts seems to be that at certain periods rabies may become locally epidemic among dogs and wolves, and by them be communicated to skunks." Thus the blame is thrown mainly upon the striped skunks, the reverse of the usual opinion in Arizona. We are referred in this work to Fur-Bearing Animals, by Elliott Coues (1877) and in this work several authentic cases of death from rabies following skunk bite (kinds of skunk not specified) are reported, four of them by a United States Army surgeon. One case of recovery from such a bite without rabies resulting is also specifically reported. Another portion of the same work deals with the report of another United States Army surgeon (John G. Janeway, M. D., Assistant Surgeon U. S. A.) who personally observed fifteen fatal cases of hydrophobia. Ten of these resulted from skunk bite (kind of skunk not stated.) Details of three of these ten cases are given, from which we learn that these three individuals were bitten in the night, one in the nose, one in the little finger, and the other in the hand.

Dr. Antonio Lagorio, of the Chicago Pasteur Institute, makes the following statement in the Tempe Normal Student, (May 15, 1908):

"I have found skunk bites to be very dangerous, and I am convinced that all persons bitten by skunks should take at once the Pasteur treatment. I have known of several deaths from hydrophobia, due to skunk bites. Last year a skunk was brought alive

Plate III.—Skins of striped skunks (*Mephitis*). All are varieties of a single species. Nos. 2, 3, and 4 are all of a variety (*mil'cri*) which has been taken in Arizona. (From N. American Fauna, No. 20.)

to me from Arizona, which had bitten two persons. Three days after the animal died with all the symptoms of hydrophobia. I have treated several persons bitten by skunks and all have about the same history of skunks creeping up during the night, and biting either the nose, ears, hands, or exposed feet, some sticking so fiercely as to have to be choked off."

Inquiry from the Rockefeller Institute for Medical Research develops that they have made no special study of rabies with reference to the skunk.

From the available information we must conclude that there is no particular species of skunk which can be designated as "*the* hydrophobia skunk"; nor should we speak of "*a* hydrophobia skunk" in any other sense than we might say a hydrophobia coyote. However, we are forced to conclude also that, rabid or not rabid, skunks are rather more apt to bite sleepers, than are coyotes, wolves, and dogs. A possible explanation of this would seem to be the undoubted fact that skunks as a rule are comparatively fearless prowlers on account of their excellent natural protection. A skunk displays no haste to get out of the way when encountered, feeling perfect confidence that the other fellow is the one to be careful.

It appears, too, that perhaps a rather larger proportion of bites from skunks produces rabies than of the bites from any other animal. Yet statistics on over 3000 cases of rabies show ninety per cent infected from dogs, and only one per cent from skunks, so that the total showing is not great. Most of us, from states farther east, never heard of a "hydrophobia skunk" until we came west, yet 41 cases reported in Coues' work "occurred in Virginia, Michigan, Illinois, Kansas, Missouri, Colorado, and Texas." It would seem that the greater fear of skunks met with here may be due, in part at least, to two causes: first, that many more people sleep in exposed situations in the open western climate; and, second, that there may have been local epidemics of skunk rabies in various western localities.

In the face of the facts and conclusions above offered, there seems to the author just one more unavoidable conclusion, and that is,—in case of skunk bite take the Pasteur treatment. This treatment is successful in more than ninety-nine per cent of cases treated before symptoms of the disease appear, and will do no harm whatever even if infection has not occurred. On the other hand, one may not wait to see whether symptoms appear, for treatment is entirely useless after that. As to whether we shall continue to

sleep out unprotected, that is a question for each individual to settle for himself.

INVERTEBRATES

The remaining animals to be treated here all belong to a quite different group, the Arthropoda, or "jointed-foot" animals, having a characteristic horny outer shell or exoskeleton, rather than a bony skeleton within the body: and those of this immense group which interest us here are the insects and their relatives the spiders, scorpions, centipedes, etc.

It is a peculiar fact that while fear of certain forms of insects is much exaggerated or entirely unfounded, yet certain other insects which actually cause thousands of cases of illness and death not only do not cause general alarm, but it is well-nigh impossible to arouse some classes of the population to their importance. These are the insects definitely proven to carry diseases of man. Such common insects as house-flies, carrying typhoid fever and other diseases; body-lice carrying the dread typhus fever; malarial mosquitoes, and the yellow fever mosquito, are examples of these. Yet the less educated people can hardly be forced to give attention or thought to these deadly, but non-poisonous, insects; while the harmless "campamocha" and "Child-of-the-Desert" are greatly feared. This bulletin is not to deal with the disease carriers, however, important as they are, for much more of both general and particular information is available concerning them than concerning other, actually less important, but poisonous or feared kinds of this region.

INSECTS

First to be mentioned among poisonous insects are bees, wasps, and ants, and they are discussed in part for purposes of illustration and comparison, since they are familiar to every one. All bees and wasps, and many ants of the Southwest, have stings with which a definite poison is injected into the wound made. All ants, whether stinging or not, attack by biting. The bite is only a pinch with the jaws and is in itself non-poisonous; but even the stingless ones possess the usual poison glands, and these are said to bring the tip of the abdomen forward and spray poison into the wound made by biting. The sting, in so far as we humans are concerned, is only a weapon of defense, never of offense, and we need not fear the bee or wasp visitor so long as we attend quietly to our own affairs and

commit no aggression. Probably no person approaching near to maturity has been so fortunate as to escape a painful experience with one of these, and it is perhaps because of their commonness and wide distribution that we do not greatly and unreasoningly fear them. As a matter of fact, they are quite as much to be dreaded as some supposedly more dangerous animals which are less common or of more restricted distribution. More than one case of serious illness and even of death is on record from the stings of ordinary honey-bees, and to some individuals a single sting is a very serious matter. We commonly recognize the fact of wide individual variation in respect to the effects of the poison of bee or wasp stings, and this principle applies equally to the poisons of spiders, centipedes, scorpions and the like. When the average person suffers comparatively little from a single sting or even from several stings at one time, a particular individual may have some peculiar characteristic of constitution or temperament which makes for serious illness with but one or a few stings. The local pain and inflammation varies somewhat, but not so much, perhaps, as the constitutional effects of the poison. It may be well to state in passing that the great majority of bees and wasps are useful insects, the former for pollination of flowers, and the latter for destruction of many injurious insects. Therefore, they should not be molested save in particular instances when they are so located as to be nuisances. This must be qualified somewhat for the ants. Many of them doubtless do great good in destroying injurious insects, but some denude an appreciable percentage of tilled ground, and some have been reported injurious to livestock. Herms reports as follows on one of the "harvester ants":

"One of the most formidable stinging ants in California is *Pogonomyrmex californicus*. This ant will not only attack humans but also small domesticated animals. Thus hog raisers in the Imperial Valley, California, report many pigs killed by ants, one farmer reporting a loss of 400 small pigs during one year and another 100 to 150 during a period of three years,—all killed by ants."

This report, Herms says, is not fully verified, yet it cannot at present be safely denied. We have this species and others of *Pogonomyrmex* in Arizona. Professor Wheeler, a distinguished authority on ants, reports on the stings of *Pogonomyrmex* kinds as follows:

"The sting of these ants is remarkably severe, and the fiery, numbing pain which it produces may last for hours. On several occasions when my hands and legs had been stung by several of

these insects while I was excavating their nests, I grew faint and almost unable to stand. The pain appears to extend along the limbs for some distance and to settle in the lymphatics of the groin and axillae."

There will be mentioned specifically here but one group of wasps, peculiar, hairy, wingless forms, called "Velvet-ants" and "Cow-killers." They are ant-like in appearance chiefly because of their lack of wings, being larger than ants (up to an inch in length) and covered with a thick pile of hairs, whence the term *velvet*. They are generally conspicuously banded with contrasting colors, oftenest black and some shade of red, sometimes black and yellow, and in a few cases black and white. They are much more abundant in the arid southwest than elsewhere. Their stings are very long and capable of inflicting a painful wound, though not more dangerous than other wasps or hornets. It is said the term Cow-killers is given them in parts of Texas, where their sting is popularly believed to be dangerous to livestock. This superstition has not yet, been met with in Arizona by the writer, but may exist in some parts. Even these are generally useful in destroying undesirable insects.

The sting of the honey-bee, which usually remains in the wound, should be removed by scraping with a knife blade or fingernail, not by grasping, the latter method resulting in forcing more poison into the wound. For stings of bees, wasps, and ants, alkalines such as ammonia or soda are generally recommended, but are of little value and should not be rubbed in if applied. Wet cloths as hot as can be borne will afford relief and "The application of wet clay, or of the end of a freshly cut potato is sometimes helpful." (Riley and Johannsen.) In extreme cases of great susceptibility or many stings, call a physician.

Several rather large (about an inch long is an average), and conspicuous insects known to entomologists as "assassin-bugs" or "cone-noses" are poisonous, and are known on occasion to attack man. "Assassin-bug" sounds vicious enough surely, but the majority, if not all of these assassinate chiefly other insects. Certain kinds, however, may attack human beings to get a meal of blood, while others attack only when carelessly or roughly handled. Even those most likely to attack us are perhaps in houses primarily to catch other insects, one such being descriptively called the "bed-bug-hunter." Some may be attracted to lights, and coming in contact with the person on face or hands, will stab quickly and vi-

ciously with the beak, especially if an incautious attempt be made to pick the intruder off with the fingers. A sudden snap of the finger is the safest means of getting rid of one of these unwelcome bugs. While there are doubtless several kinds of this group native to the Southwest, of which probably Arizona has its full share, the writer of this bulletin has had no personal reports of injury, and only a single unlabelled specimen is at present in the University collections. At this juncture we will depend for local information upon Dr. A. W. Morrill, State Entomologist. In a paper published in the Arizona Medical Journal, January, 1914, he says:

"In many parts of the Southwest there is a large relative of the bedbug, known as the blood-sucking conenose, belonging to the genus *Conorhinus,* which is quite troublesome as a household pest. Other common names for this insect are "Arizona bedbug," "bellows bug," and "Arizona tiger." This is one of the species which contributed to the kissing bug scare of 1899, which 'encouraged by the newspapers,' says one entomological writer, 'resulted in one of the most interesting cases of widespread popular alarm arising from a comparatively insignificant cause, which has occurred in the present scientific and matter-of-fact century.' It is a fact, nevertheless, that there is considerable evidence that the Arizona blood-sucking insect above named transmits pathogenic (disease producing) organisms. The sting of this bug frequently produces red blotches on the body, as reported by one of my correspondents, and in one case reported from Arizona several years ago the effect of a single sting is said to have produced 'red blotches and welts all over the body and limbs.'"

Dr. Morrill further informs me by letter that the localities from which he has had such reports of injury are Fort Apache, Cottonwood, and a ranger station about twenty-five miles north of Clifton.

A figure (Fig. 2) of any one of these showing the general charactersitics of elongated body, and slender, cone-shaped head (cone-nose) with strong beak beneath, and protruding, rather fierce looking eyes, will enable one to be on guard. These insects really neither bite nor sting, but *pierce.* That is, the wound is made with beak-like mouth parts which cannot bite by pinching, but which penetrate the skin in the manner of a sting, like the "bite" (piercing) of a mosquito. A poisonous saliva is injected into the

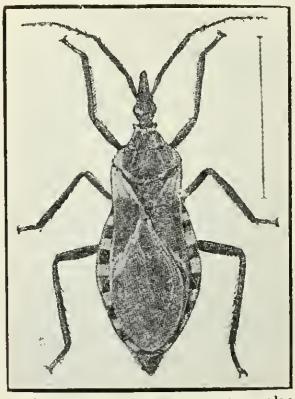

Fig. 2.—"Cone-nose blood sucker" or Arizona bed-bug (*Conorhinus sanguisugus*) enlarged about twice. (From Insect Life.)

wound through the beak. The wounds are said to be very painful for a time, even leading to nausea and dizziness, but are hardly to be regarded as dangerous, save possibly in the case of a child or a person of very weak constitution, or in the event of a germ infection following. Herms thus describes his own experience in accidentally grasping a cone-nose on a leaf:

"The bite was instant and the pain most intense, and though the wound was on the finger the pain seemed to extend to the head and was followed by a feeling of faintness. The recovery, however, was a matter of less than half an hour with no after effects except for a slight local cellulitis."

There are two innocent, non-poisonous insects which attract much attention in the Southwest, and are feared without cause. The first of these is known as the "sand cricket," or sometimes as the "Jerusalem cricket" and also as "Child-of-the-Desert," the last appellation being the most used of the three in Arizona. This insect is merely a peculiarly shaped wingless grasshopper, whose habits and life history are not fully known. (Fig. 3).

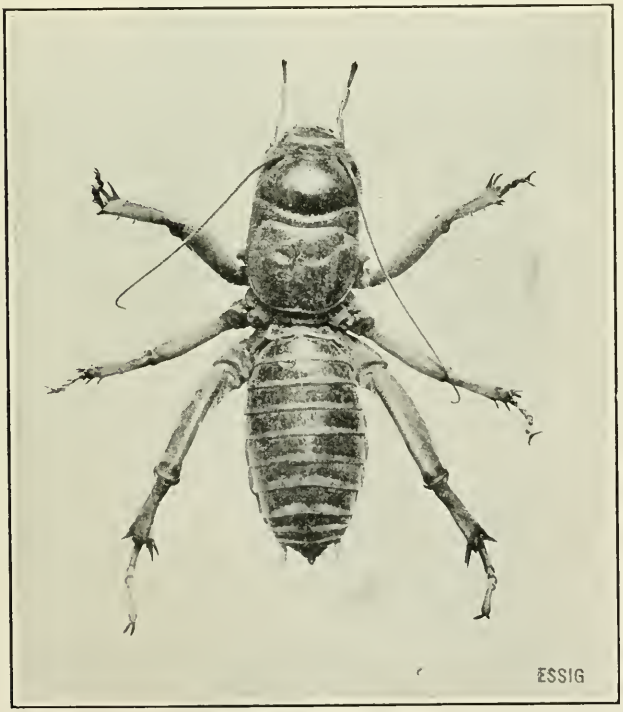

Fig. 3.—The Sand or Jerusalem cricket (*Stenopelmatus irregularis*). Somewhat enlarged. (From the Monthly Bulletin of the California State Commission of Horticulture.)

It is entirely harmless, save that its biting jaws are somewhat larger and more powerful than those of the ordinary grasshopper,

so that it is able to nip one somewhat severely in self-defense. It is quite without poison. I have myself been bitten by one, with no more effect than from a similar nip with a pair of forceps. It is heavy or plump-bodied, without wings at any stage, cream colored, with large creamy or light brown head. This large head is smoothly rounded, bald, without the angles common to most grasshopper heads, and has often been described to the writer as resembling "a baby's head." From this common conception of its appearance doubtless arose the name "Child-of-the-Desert." It is a burrower in sandy soils and probably seldom appears on the surface except at night, which perhaps accounts for its being sometimes confused with the "vinegarone." Indeed, Miss Anita Post, of the Department of Romance Languages, assures me that the Mexican population regularly call it by the same term (mata venado) as the other animal, which will be discussed later in this paper. "Sand-cricket" is the simplest and best term to use for this insect.

Fig. 4.—The praying mantis. Photograph from life, natural size.

The second of these insects is the praying mantis, called commonly by the Mexicans the "campamocha." This insect (Fig. 4), we will grant is eerie in appearance as it rolls about its very mobile head, with the prortuding, staring eyes, in odd fashion. The popular superstition with regard to this is that if accidentally eaten by a horse or cow the result will be fatal. This seems to be a local variation of the belief referred to by Comstock in his work on insects, in which he says:

"They are also called mule-killers, from the absurd superstition that the dark-colored saliva they eject from their mouths is fatal to the mule."

There is also about as much reason in this prejudice as there would be basis for saying that the "tobacco juice" of the grasshopper is a deadly poison. The praying mantis is really a *preying* mantis. Lying in wait for the insects upon which it preys, it uses the long grasping forelegs, borne on the up-reared front part of the body (whence the name "rear-horse") for seizing the hapless victim. It is distinctly a useful insect and innocent of harm. Indeed, one of these makes a most interesting pet if kept in a small cage and supplied with flies or other small insects.

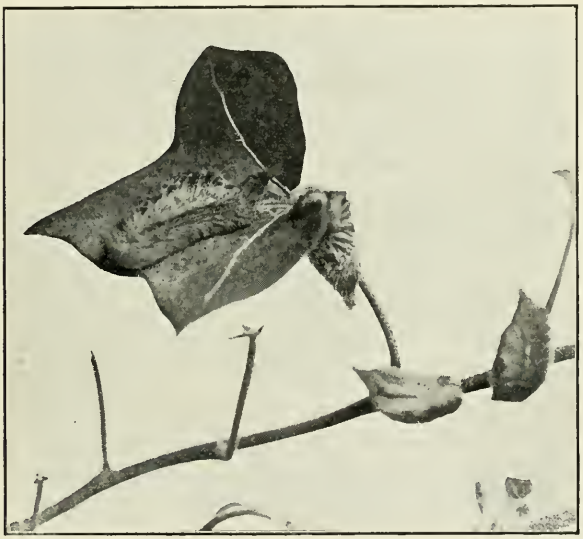

Fig. 5.—Flannel moth larvae on English ivy. Three-fifths life size. Photograph from life.

Last of the insects to be mentioned will be certain moth larvae known as flannel moths. These are "woolly caterpillars" whose hairs are so thick and oddly arranged as to give great resemblance to a bit of flannel. (Fig. 5).

Hidden beneath the thick covering of long, soft, harmless hairs, however, are groups of stiff bristles or spine-like hairs. These will penetrate and break off in the skin, producing a rash much like that caused by a nettle, hence called nettling hairs. Two species of these flannnel moths are known further east, but have not been reported from Arizona. In September, 1917, however, specimens of flannel moths, which may or may not prove to be one of the kinds already known, were sent to the University from Tombstone, by Mrs. Julia R. Axtell, with the report that they had destroyed a fine wall of English ivy, and that "In some way it seems to poison

everyone who happens to touch it." Observing some care, I have been able to handle with my fingers, several of the live specimens in rearing cages without injury to the thick skin within the hand. Having accidentally brought the back of my thumb in rough contact with one, however, I almost immediately began to feel the effects of the nettling hairs. Using no treatment, I found that the effects became rather more severe than a like amount of contact with nettles. The pain, while not intense, was sufficient to enforce itself on my notice and was rather more of an aching pain and less of an itching or burning sensation than nettles. For three hours this was allowed to continue, then a wet paste of baking soda was applied, and this soon relieved the pain. Soda seemed much more efficacious for this purpose than for a bee sting. The following day all pain was gone, only a few slightly raised red points, somewhat sensitive to touch, remaining.

SPIDERS

Of the invertebrates with which this bulletin deals, spiders are perhaps the most universally feared. This being true, and since Arizona lies in that region of the country in which are found several of the most dreaded kinds, we shall deal with this subject in considerable detail, taking care to be as definite and explicit as possible. In the first place, it may be said that while there appear in the public press frequent accounts in convincing detail, of persons having suffered more or less severely from spider bites, investigation of these reports shows little foundation in fact. Scientific men attempting to follow up and authenticate these accounts, either fail utterly to find the supposed victim, the case being imaginative or fictitious, or, on finding the victim or the physician in the case, learn that the injury is only *supposed* to have been inflicted by a spider; and often, too, that whatever the original cause, the effects noted are due to germ infection of the wound and not to a venom. Probably many reported cases of spider bite, are in reality made by cone-noses. Spiders do have definite poison glands in the head or bases of the claw-like biting jaws, and these discharge their poison through ducts leading through the jaws; and this poison is regularly used in paralyzing prey. But as has been pointed out by authorities, venom that will kill a fly is not necessarily harmful to man.

Now, do spiders use their jaws and poison freely in self-defense against man? The very common belief is that they do. The

writer's own experience in occasionally catching spiders is that they do not. Professor Comstock reports that in years of study of spiders, involving the handling of very many live specimens, he has never been bitten. Others bear out this evidence with personal experience, and emphasize also the lack of power to do damage by reason both of the small size of the jaws and the inconsiderable effect of the poison itself. Dr. Riley says, "Some years ago the senior author (himself) personally experimented with a number of the largest of our northern species, and with unexpected results. The first surprise was that the spiders were very unwilling to bite and that it required a considerable effort to get them to attempt to do so. In the second place, most of those experimented with were unable to pierce the skin of the palm of the hand, but had to be applied to the thin skin between the fingers before they were able to draw blood * * * In no case was the bite more severe than a pin prick and though in some cases the sensation seemed to last longer, it was probably due to the fact that the mind was intent upon the experiment." Other men have experimented with similar results. Certainly we must conclude that the ordinary spider is anything but dangerous.

Certain exceptions to the above general rule cannot be disposed of quite so readily, particularly in the southwestern area of which Arizona is the center. These exceptions are the many and various large hairy spiders dubbed tarantulas at sight, and a certain small black species found 'in the South' and hence doubtless within our borders.

Fig. 6.—Crab-spider. Photograph from life, natural size.

Tarantulas are among the most dreaded of all spiders by the average person. Let us emphasize just here the spelling and pro-

nunciation of the word, *ta-ran-tu-la*. The word is often senselessly corrupted to "triantler." The term tarantula was originally given to a European spider, the bite of which was supposed to produce tarantism, a form of hysteria. This hysteria, once started, often became contagious, but was purely a nervous disease. There is no evidence that the bite of a spider was responsible for even the first case of a given outbreak. The tarantulas of the Southwest belong to a family of spiders entirely different from this European form, and the name, moreover, applies to trap-door spiders as well, which belong to this family. Several kinds of rather large, long-legged, somewhat hairy spiders which run swiftly are also often called tarantulas, and are supposed by many to be the young. This is likewise true of the crab-spiders (Fig. 6) which are represented in our fauna.

One of the crab-spiders is often found in bunches of bananas, and is an object of fear, but true tarantulas are much less often found in this situation. This banana spider is quite harmless, as are other crab-spiders probably, a personal friend of the writer's having captured many with his bare hands without ever being bitten. One of these crab-spiders has been received from Nogales labeled "white tarantula," indicating that it may be accounted dangerous. While most tarantula species are dark or black in coloration, this "white tarantula" and many other crab-spiders are gray, or of very light color.

Fig. 7.—A tarantula. From a dried specimen, slightly reduced.

Tarantulas (Fig. 7), like other spiders, have poison jaws for killing or paralyzing their prey, and their formidable size would indicate that if their poison be at all virulent, a bite might produce marked effects on a human being. Even on this point there is no experimental evidence whatever regarding American species, but the poison from a single individual of a species from Haiti has been found sufficient to kill ten

sparrows or twenty mice. That from a Corsican species was equally powerful, but with effects on sparrows and mice reversed.

In the course of preparation of this bulletin the writer was quite surprised on failing completely to find any record of a case of tarantula bite. Original sources were not available to any extent, but when the authors of three special works have similarly failed to find such record it may reasonably be supposed that it is non-existent. At this juncture we had recourse to inquiry from physicians of Tucson. Five were consulted with the following results: Two reported never having seen a case of tarantula bite, and one of these has had twenty-five years' experience in Tucson. Of the other three, one reported two cases; the second, with twelve years' experience, had himself been bitten on the leg, and had seen three other cases in addition to his own; while the third of these, with thirty-six years of practice in Tucson, had seen but one case. Since there seem to be no other records, these cases are worth stating specifically.

Case 1 was that of a railroad laborer bitten on the hand. The arm became much swollen to the shoulder and became discolored with suffused blood,—"black-and-blue." The more serious results lasted two or three days, but a state of depression lasted for some time, and complete recovery took some weeks. This case was bitten in daytime on accidentally bringing the hand in contact with a tarantula, in the act of turning over a stone.

Case 2 was an old man 70 years of age, Mexican, bitten on the side of the neck in early morning. When seen by the physician several hours later the neck was badly swollen, the line of the chin continued straight down to the body. Numbness was at first experienced. Recovery was a matter of a few days. The tarantula was killed.

Case 3 was bitten on the lip. Numbness and much swelling followed, as in Case 2. The tarantula was killed and brought to the hospital with the patient.

Case 4, the physician, was bitten on the leg several years ago, and scar still remains. This physician reports his own case and the other three attended by him as swelling somewhat, though not extensively, and as becoming blue from sub-cutaneous hemorrhage, the blueness lasting for a long period. In these cases is also reported a digestive action from the venom, resulting in sloughing ulcers, which were very slow to heal.

These cases are unquestionably authentic, as to the animal re-

sponsible, and as to the severity of the results. The details concerning the effects, while not identical, are sufficiently similar to show the possible seriousness of a tarantula bite. On the basis of the facts learned, I should say that tarantulas are not nearly so prone to bite human individuals as is generally supposed, since but seven cases have been seen by five reputable physicians with an aggregate of more than a hundred years of practice in Tucson. I believe, also, that while the injury produced is quite severe, and somewhat serious, yet it is hardly to be considered actually dangerous to life for the average healthy, full-grown individual. One physician consulted suggested the possible danger in case the poison should be injected by the jaws into a good-sized blood vessel, and we can agree with that, yet recognizing that the likelihood of the animal so injecting the poison is not very great, on account of the size of the jaws. These are large for a spider, but not to be compared in length with the fangs of a rattlesnake. For a child the bite would likely be very serious and quite possibly fatal. Indeed, one unauthenticated case of death of a child in Tucson has been reported to me.

Some of the reported cases of spider injury state that the injury was inflicted by a "small black spider," and these reports are more likely to have a basis in fact as to ill effects than other stories of spider injury. There is a certain species of small black spider, about one-half inch long,—the "black widow," or "shoe-button spider," *Latrodectus mactans*, which is seemingly a somewhat formidable exception to the general rule concerning small spiders. This kind is reported from "the South," not specifically from Arizona, but doubtless exists here. Experimental evidence shows that this and other species of *Latrodectus* from various parts of the world have a much more virulent poison that ordinary spiders. This is borne out by reported cases, while in the various countries where they are native these spiders are almost universally held to be dangerously poisonous. Among them are the dreaded "Malmignatte" of southern Europe, the "Katipo" of New Zealand, the "Vancoho" of Madagascar, the "Karakurte" of southeastern Russia, and our own kind, called "Po-ko-moo" by certain California Indians. The latter, according to Merriam, as quoted by Comstock "rank it with the rattlesnake as *poison*. To poison their arrows they mash the spider and rub the points of the arrows in it." The symptoms produced experimentally agree with the symptoms of persons who have been snake bitten. There are several cases on record of severe

symptoms following the bite of this species, one of which ended fatally. This may even then have been an exceptional case due to personal condition or even in part to fear. As I read over the account of this and another severe case from the same locality (North Carolina) I cannot but wonder whether the reported dosage with alcohol may not have put the fatal touch upon the one case and the nearly fatal touch upon the other. We know now that whiskey is the worst thing to give at certain stages in rattlesnake bite, notwithstanding popular opinion to the contrary, and it may well be so in the case of the bite of this spider. A case is personally reported to me from Yuma, Arizona, of a bite from a black spider, doubtless this or a related species. In this case the victim, a lady, was bitten on the hand and serious "symptoms of blood poisoning" followed, which it required some weeks to cure.

This exceptional spider is easily recognizable, being shiny black, with red or yellow markings. An hour-glass shaped mark on the lower side of the abdomen is the most constant of these marks. Spots may in addition be found along the middle of the back. The male has in addition to these, four pairs of stripes on the sides of the abdomen. A gray species of this genus has been described from California, and may belong to our fauna, but no reports are available concerning injury from it.

MATA VENADO

Near relatives of the spiders are the peculiar creatures commonly known in this region as the "vinegarone" (Fig. 8), of which five kinds are definitely reported from Arizona. This is called in local Spanish *mata venado* (kill deer). Others occur in Colorado, New Mexico, and California, and it is likely that one or more additional kinds may be found here. Twelve species are at present known in North America north of Mexico, so that probably half the kinds now known are native to this State. All are restricted in distribution to the West and to the Southwest. These creatures are accounted rather rare by writers, but we believe that their nocturnal habits (one or two kinds are said to be diurnal) makes them seem to be less plentiful than they really are. They hide by day in holes and under stones and rubbish and come forth by night for insect prey. They are very active when engaged in killing ants, and have been called wind-scorpions on account of their speed and agility in pursuit of their prey. They have been called sun-spiders also, presumably some diurnal kind receiving this name. The characteristic

shape for all is sufficiently uniform that the accompanying cut of one will serve to identify any kind of "vinegarone." Attention may be directed to the peculiar fact of possessing *four* pointed jaws, this causing the head to be of very different shape from that of the "Child-of-the-Desert" with which it is frequently confused. Its body is somewhat hairy, also, while that of the insect alluded to is smooth and shiny. Color and nocturnal habits are about the only actual resemblances between the two, this animal being creamy to light brown. The much used, and misused, term vinegarone does not rightly belong to this animal, it seems, but to a peculiar scorpion, which will be mentioned later.

Fig. 8.—Solpugid (mata venado). Also called (wrongly) the vinegarone. Photograph from life, natural size.

These animals are accounted poisonous and are held in great dread by the Mexican population, this fear having been more or less communicated to the white residents also. In spite of having heard personally of two instances in which humans were bitten, with some resulting symptoms which would seem to indicate a poisonous bite, the writer must admit his own skepticism as to their dangerous character. This view is held, first, because examination by competent authorities has failed to disclose the presence of any poison glands in the biting apparatus, and second, because observers submitting voluntarily to being bitten have not suffered any ill effects indicating poison. The bite as such is likely rather severe, as the jaws are large and powerful. Herms reports that in the neighborhood of the Salton Sea, the belief exists that any animal drinking from a watering trough in which one of these happens to be present will die.

When living specimens can be secured and kept long enough to permit of observations and experiments worth while, the subject may be checked up for one or more of the Arizona species. In the meantime we wish to emphasize the almost certainly harmless nature of these animals so far as poison is concerned, and will conclude with the following quotation from Comstock, which is brief and to the point:

"The solpugids are commonly believed to be venomous; but those who have studied them most carefully do not think that this

is so. No poison glands have been found, and observers have allowed themselves to be bitten by solpugids without suffering anything worse than a passing pain from the wound." (Zoologists know these animals as *solpugids*).

SCORPIONS

Other forms closely related to the spiders are the scorpions (Spanish, *alacran*), so commonly known in Arizona as hardly to need any description or illustration. (Fig. 9). They are common in the warm southwestern regions, though unknown in the north. A considerable number of species occur in this area of the United States, and Comstock lists seven kinds with ranges which indicate that they probably belong to our fauna. A full study of them may disclose more than seven. It may be emphasized that the scorpion does not bite, having no mouth parts capable of inflicting injury on the human body, nor does it do injury by means of its "pincers." The scorpion stings by throwing the slender part of the abdomen (so-called tail) up and forward over the back and striking forcibly with it, the curved spine or sting being driven with sufficient force to make the wound. Having observe them paralyze insect prey with a more deliberate working in by continued pushing of the sting, we conclude that it may penetrate the human skin in the same way, under circumstances that do not permit of its striking, as when caught in a shoe by the foot. There is a well developed poison gland in the bulbous base of the sting.

Fig. 9.—Scorpions, one-half life size. The smaller one is not the young of the larger, but is a mature specimen of its kind.

In the whole literature on scorpions, which belong to all hot regions of the world, will be found many statements which are apparently conflicting regarding their dangerous or poisonous character. An analysis of these statements indicates that the sting of some of the largest species in other countries than our own may be dangerous, even to adults, and accounts of numerous deaths of children in Mexico are given. But some of these kinds are many

inches in length, much larger than any Arizona species, though size is not in itself an indicator of comparative harmfulness. Certain small dark scorpions in Arizona are commonly reputed to produce a more painful wound than the larger ones. We wish to emphasize that fatal, even serious, results from the sting of any Arizona scorpion are no more probable than such results from the sting of a honey bee. Yet many a person has such an unreasoning fear of a scorpion as to believe that it is time to make a will when stung. In such cases fear produces greater shock effects than the sting itself. Personal acquaintance with many who have been stung, and conversation with physicians, is convincing proof that we need fear them no more than, if as much as, the ordinary bee or wasp.

The Whip Scorpion probably occurs in Arizona, and is much feared where it is known. (Fig. 10). We are assured by those who have handled this animal alive that it does not bite or pinch, and it certainly has no sting on its whip-like tail and may safely be accounted non-poisonous. It gives off an odorous substance for protection when disturbed, which resembles the odor of vinegar, and to it in Texas the name vinegarone was applied. There seems little doubt that this is the correct and original use of this word, though it is now most commonly applied in Arizona to the solpugid, as noted above. In some parts of the South this is called a "grampus."

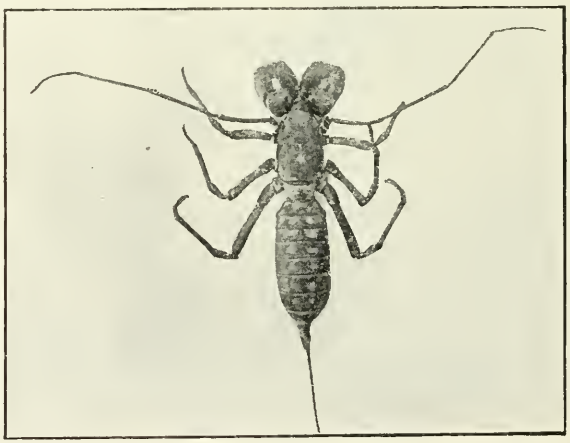

Fig. 10.—Whip scorpion. Two-thirds life size.

MYRIAPODS

Second only to the tarantula, if not, in fact, its co-equal as an inciter of fear, is the centipede (*cientopies*), another nocturnal prowler. (Fig. 11). Strangely enough the many small species of these so common under sticks and stones throughout the United

States are scarcely recognized as being in fact centipedes. These small species are entirely harmless to man, though possessed of the same poison apparatus for killing prey as the larger ones. As the more tropical regions are approached larger kinds are found, until, in the equatorial regions, some are said to reach a length of eighteen inches. In Arizona specimens eight inches in length are not rare, and the maximum size reported to the writer is one foot, this, however, being an estimate, and not an actual measurement. The term centipede and cientopies mean literally *hundred feet,* and in some parts of our country the small ones are known as "hundred-legged worms." As a matter of fact our largest local species has considerably less than one hundred feet, the number being forty-four, or twenty-two pairs. Some smaller but more slender species have as many as 173 pairs. These counts include in every case an anterior pair which act as poison claws or jaws, and a posterior pair somewhat modified and held in an elevated position, the latter being often mistaken for antennae. In this way arises an existing confusion as to which is the head end of the animal. I have even been asked whether there is a head on each end! The front pair of legs is laid forward beneath the head, where they act as a pair of jaws moving laterally, and within their bases lie the poison glands. Insects are almost instantly killed when seized with these jaws and are then eaten by means of less conspicuous true mouth parts.

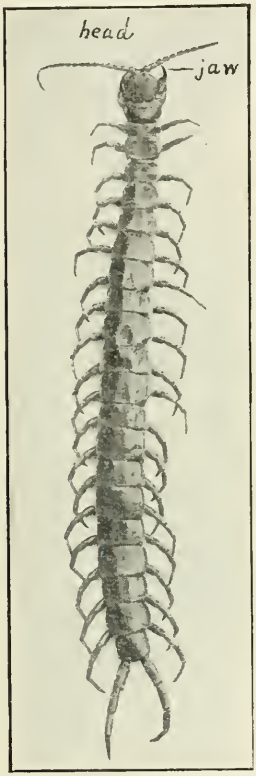

Fig. 11.—Centipede. Two-fifths life size. Poisonous.

Various texts and references prove to be quite indefinite in their statements so far as specific cases of effects of bites on humans inflicted by American species are concerned. All agree as to harmlessness of small kinds, as to effect of poison on prey, and as to painfulness and possible danger from the largest ones. For effects and possibilities of local kinds we must again depend on local experience, which is definite. The writer has personally known of two cases of centipede bite. In one of these instances a then member

of the University staff was bitten on the upper arm about 11 p. m., by a large specimen, about seven inches long. Hydrogen peroxide was applied. (This would prevent germ infection of the wound, but probably would not counteract the poison.) Pain at first was like pin pricks, but in about an hour became severe, preventing sleep. Two prick marks showed, which were pink, red, then whitish in center, then purple. In the morning at five a physician was sought, who advised putting on baking soda. The arm became swollen and very painful, with sharp pains. Swelling and pains extended downward into the hand and lasted all day. Some feeling of faintness and nausea occurred at times next day and slight pain across abdomen also. Pain was severe all next day (Friday) and "might not have slept Friday night, but had sleeping tablets from physician." On Saturday the pain was gone except when the hand or arm was touched. On Monday afternoon still slightly painful to touch; swelling gone. Still slightly painful to lift arm. (Some of the symptoms given, the writer believes, may have been due to undue nervousness as to effects, as the victim in this case was undoubtedly somewhat wrought up about it). In the other instance a lady was bitten about 11 p. m. on the heel, through a reinforced portion of the stocking, the animal being seven or eight inches in length. The bite was described as feeling like a hot needle at the instant of infliction. The pain following was described as a recurrent throbbing or stabbing, and sleep was prevented, though the victim asserts she does not really know whether this was the result of the pain itself, or the excitement of the occasion. Only slight swelling appeared in this case, and it was gone within twenty-four hours. Patient was about the next day, shopping down town in the afternoon, but could still feel throbbing pains. After two days all effects had disappeared. Asked as to the comparative effects of a bee sting, this lady immediately stated that the only bee sting she had ever suffered was worse, producing the same sort of throbbing pain, and that it lasted much longer. It must be said that the centipede bite having been inflicted through the clothing was probably not as bad as it otherwise would have been, but would in any case hardly have been worse than the bee sting. While these effects were severe in both cases, it will be seen after all that honey bee stings are of at least equal severity in many cases. One should certainly avoid these injuries when possible, yet there is absolutely no reason for the unreasoning fear of the centipede, as compared with the relative calmness about bees.

One hears many statements as to the poisonous character of *all* the claws of the centipede. These vary from the supposition that a centipede merely walking undisturbed across the skin leaves an inflamed trail, to the story that one cannot be removed from the skin, however suddenly (even by shooting it away with a six-shooter!), without its sinking every claw into the flesh and leaving a line of severe wounds; even so severe that sloughing of affected flesh follows. There are certainly no poison glands in any other than the specialized front feet. Yet the claws are sharp-pointed, and a reputable physician assures me that he has seen an inflamed path across the skin, but this in case where the animal has been grasped and irritated in contact with the skin, as when within the clothing. Even in this case the physician admitted the possibility of several bites in succession having been received. On the other hand, the writer admits the possibility that the claw points might produce irritation comparable to so many pin pricks if the animal were caused to cling tightly to the body. Local physicians agree with the writer that centipede injury is only to be classed with the sting of the scorpion in severity, and both of these with bee and wasp stings.

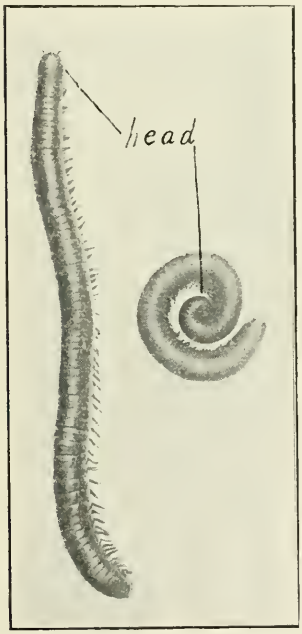

Fig. 12.—Millipedes. One-half life size. Harmless.

A non-poisonous, perfectly harmless animal which causes needless fear is the millipede or "thousand-legged worm." (Fig. 12). It is also called wireworm on account of its smooth, hard body covering, but should not be confused with the wireworm, which is a type of small, smooth, hard, almost legless insect larvae, none so large as the millipedes. Millipedes are of a group related to the centipedes in structure, but differing in habits and in certain easily recognizable characters. Centipedes are flat bodied and each segment or "joint" of the body bears one pair of legs. Millipedes are cylindrical bodied, and each apparent segment bears *two pairs of legs* They feed only on vegetable material, hence have no poison apparatus, and their mouth parts are too small and weak to inflict even

the slightest injury on the human skin. They secrete an ill-smelling fluid for protection when handled. Locally, we have some very large representatives of the group, as long and thick as a lead pencil when they are fully extended. They commonly curl up into a tight coil when disturbed. It may be said in closing that "thousand legs" is no more accurate for these than "hundred legs" for centipedes, yet the larger ones do have a number so great that the average person does not think of counting them, and one wonders what kind of a poem might have resulted had these instead of centipedes been the object of investigation in the following instance. Professor E. Ray Lankester, an eminent English zoologist, some years ago attempted "to study the order in which the legs of Centipedes moved, and came to the conclusion that if the animal had to study the question itself, it would not get on at all. He finishes with the following verses:

"A Centipede was happy quite
Until a toad in fun
Said, 'Pray which leg moves after which?'
This raised her doubts to such a pitch,
She fell exhausted in the ditch,
Not knowing how to run."

University of Arizona, College of Agriculture

Agricultural Experiment Station

Twenty-Eighth Annual Report

For the Year Ending June 30, 1917

(With subsequent items)

Consisting of reports relating to

Administration,
Agronomy, Botany, Horticulture,
Plant Breeding, Animal Husbandry,
Entomology, Chemistry,
Irrigation Investigations,

And including a report on

Agricultural Education

Tucson, Arizona, December 31, 1917

University of Arizona, College of Agriculture

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Tucson, Arizona, December 31, 1917

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(Regents of the University)

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The State Superintendent of Public Instruction

Appointed by the Governor of the State

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William V. Whitmore, A.M., M.D.....Chancellor
DeLore Nichols, B.S.....County Agent, Coconino County
Hester L. Hunter.....Secretary Extension Service
Frances M. Wells.....Secretary Agricultural Experiment Station

The Experiment Station offices and laboratories are located in the University Buildings at Tucson. The new Experiment Station Farm is situated one mile west of Mesa, Arizona. The date palm orchards are three miles south of Tempe (co-operative U. S. D. A.), and one mile southwest of Yuma, Arizona, respectively. The experimental dry-farms are near Cochise and Prescott, Arizona.

Visitors are cordially invited, and correspondence receives careful attention.

The Bulletins, Timely Hints, and Reports of this Station will be sent free to all who apply. Kindly notify us of errors or changes in address, and send in the names of persons who may find our publications useful.

Address, The Experiment Station,
Tucson, Arizona.

LETTER OF TRANSMITTAL

To His Excellency, The Governor of Arizona,
Executive Department, Phoenix, Arizona.

SIR: I have the honor herewith to transmit to you the Twenty-eighth Annual Report of the Arizona Agricultural Experiment Station, of the College of Agriculture, University of Arizona, for the fiscal year ending June 30, 1917.

This report is made in accordance with the Act of Congress, approved March 2, 1887, establishing Agricultural Experiment Stations, and the Act of Congress, approved March 16, 1906, known as the Adams Act.

Faithfully yours,

R. B. VON KLEINSMID,
President.

President R. B. von KleinSmid,
University of Arizona,
Tucson, Arizona.

DEAR SIR: I submit herewith the Twenty-eighth Annual Report of the Agricultural Experiment Station of the University of Arizona, College of Agriculture, for the fiscal year ending June 30, 1917, with subsequent items.

This report relates to the administration of the Station and to the work in Agronomy, Botany, Plant Breeding, Horticulture, Animal Husbandry, Entomology, Chemistry, and Irrigation Investigations, and includes a chapter on Agricultural Education.

Very truly yours,

R. H. FORBES,
Dean and Director.

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Papago sweet corn, producing 23 tons of silage per acre, at the Prescott Dry-farm.

Twenty-Eighth Annual Report

ADMINISTRATION

A general survey at this time of the agricultural field in Arizona is especially interesting by reason of rapid developments now being made, and is also of value to the Experiment Station in adjusting its work to the economic needs of the State. Abnormal demands for agricultural products of all kinds have of course resulted in an unusual inflation of prices and this in turn has stimulated agricultural development to an extent not heretofore experienced in the farming history of the State. Not only has the agriculture of older irrigated districts been greatly intensified and improved, but considerable areas not heretofore improved successfully have received attention and in many cases have entered upon active development. In portions, also, of the dry-farming sections of the State, especially from 4,000 to 7,000 feet elevation, many new homesteads have been entered and dry-farming efforts have met with measurable success, more particularly where silos and livestock have been employed.

The irrigating water supply has continued to be unusually good during the season, especially, as in the case of Salt River Valley, where ample storage is available. The grazing industries, however, in common with extensive sections of the West, have experienced a considerable shortage of feed, due to the less than usual rainfall of the past winter. Spring rains in the northern part of the State were excellent, and where properly conserved in the soil undoubtedly contributed to the production of dry-farmed crops of corn, milo maize, beans, Sudan grass, potatoes, and other hardy crops. On the whole, however, especially in the southern sections, the moisture supply has been inadequate, and results from dry-farming operations less than the previous year. The exigencies of dry-farming in Arizona clearly indicate the great importance to arid region farmers of *silos* by means of which even scanty crops of

forage can be harvested and preserved in almost undiminished value, for a period of years if necessary, until the silage is needed to tide livestock over one of the periods of drought that the farmer is sure to experience in this country. Not only are silos indispensable in connection with dry-farming operations, but they are also essential for preserving forage values produced under irrigation. In the hot, dry climate of Arizona losses in nutritive value of sorghums, Indian corn and other forages in the dry state is undoubtedly greater than in the East, where the custom of cutting and preserving these materials as fodder originated. Here, therefore, where these supplies are at best not adequate to the needs of livestock in time of shortage, it is more than usually important to preserve the nutritive value of irrigated forages to the utmost by means of silos. It is not too emphatic to say that silos will soon be recognized as the backbone of the Southwestern livestock industry, both on the range and on irrigated farms.

Under the influence of increased prices for agricultural commodities, many interesting economic reactions have taken place. For instance, the high price of cotton has resulted in the conversion of considerable areas of alfalfa into cotton land. This in turn has tended to enhance the price of alfalfa hay and along with it that of other feeds; and this again, by making the profitable feeding of inferior livestock impossible, has resulted in a strong tendency towards improvement in the quality of livestock throughout the State. Many other instances of reaction due to changed agricultural conditions within the State might be enumerated. The general effect, however, has been strongly in the direction of improved methods, better livestock, and greater returns for the farmer everywhere.

Of interest at a time when unusual efforts are being made to increase agricultural development within the State, are the helpful financial agencies available for the use of the farmer. The recently organized Federal Land Bank of Berkeley, California, is one such, being in charge of Federal farm loan business for this State. Arizona State funds also, derived from the sale of State lands, are available in long-term farm loans at a moderate interest, and considerable amounts have already been distributed from this source. With increasing assurance of agricultural permanence and stability, money from private sources is also more easily available and at more moderate rates of interest than in the older and more prosperous days of farming developments within the region.

It is at this time therefore a pleasure to those who are concerned in the agriculture of the State to note general conditions of prosperity and to feel assured that many of the remaining problems of reclamation, production and profitable farm management within the State are, in the light of experience already gained, now easily possible of solution.

ARGICULTURAL EXPERIMENT STATION WORK AND FACILITIES

The lines of work at present being handled by the Experiment Station are indicated by the list of projects on following pages, being in many cases continuations of experimental undertakings of long standing. Cultural facilities have been much improved during the last two years, and since the field equipment is now fairly complete it is interesting as a matter of record to describe the different cultural areas operated for experimental and demonstration purposes by the Station, and to indicate the possibilities of future usefulness that reside in them.

THE TEMPE DATE ORCHARD

The oldest of the properties now cultivated by the University of Arizona Agricultural Experiment Station (dating from 1899) is the Tempe Date Orchard (co-operative with the U. S. Department of Agriculture), which consisted originally of 15 acres of land in the northeast corner of the N. E. ¼ of Section 3, Township 1 S., Range 4 E., G. & S. R. B. & M. To this area was added subsequently 10 acres immediately west of the original 15 acres, making a tract of 25 acres in all. This tract, three miles south of Tempe, Arizona, consists of a heavy subirrigated alkaline Maricopa loam soil in which the date palm has thus far proved to be the only remunerative crop that can be grown. Tamarisks, oleasters, bermuda grass, asparagus, salt bushes and a few unimportant weeds also survive in this very salty soil, but without economic return. It is therefore of interest to note that under such untoward conditions the date palm has succeeded beyond expectation and at this orchard the commercial possibilities of a number of the best adapted varieties have been convincingly demonstrated.

At this orchard have been solved problems relating to culture of the palms, the control of scale insects and the ripening and marketing of the fruit. With the development in addition by the U. S.

Department of Agriculture of a method of rooting a high percentage of date palm suckers, the last serious problem relating to date palm culture has been solved; and the way has been prepared for the

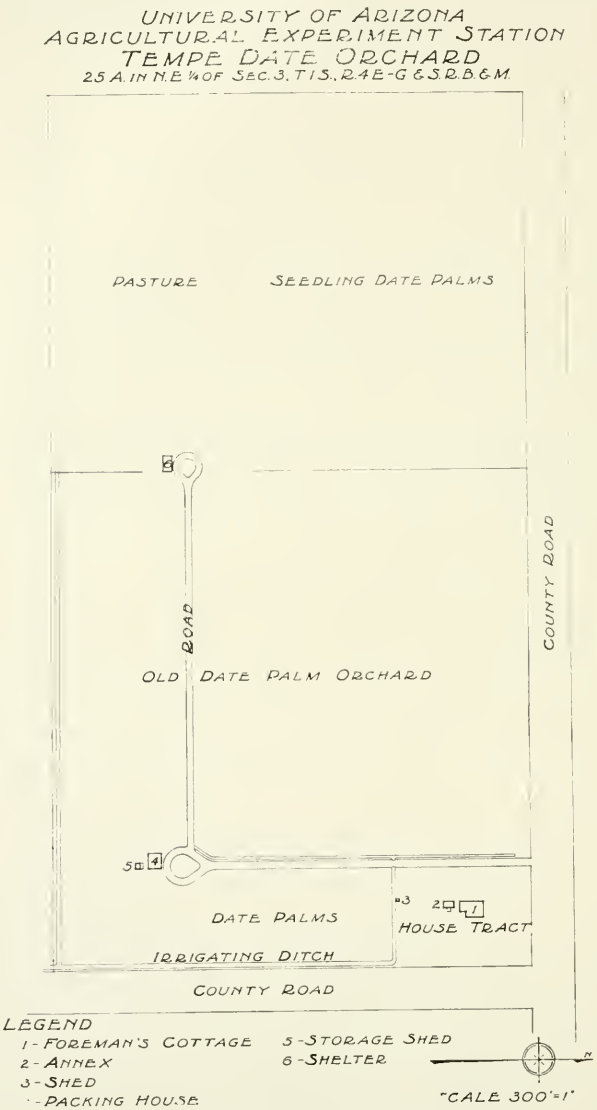


Fig. 2.—Elevation 1175 feet.

development of an extensive industry. The progress of this industry is at this time slow, partly for the reason that foreign offshoots are not now available, and partly, again, for the reason that home-

grown offshoots can be had only in limited numbers. The time required for date palms to come into bearing also deters many from investing time and money in them; but there can be no doubt of the ultimate commanding place which the palm will find in Southwestern agriculture.

The Tempe Date Orchard, therefore, with its annual crops of delicious fruit, should for many years to come remain a guiding landmark, and an inspiration towards the further development of an interesting and valuable horticultural industry.

THE YUMA DATE ORCHARD AND HORTICULTURAL STATION

This area, located in the fertile flood plain of the Colorado

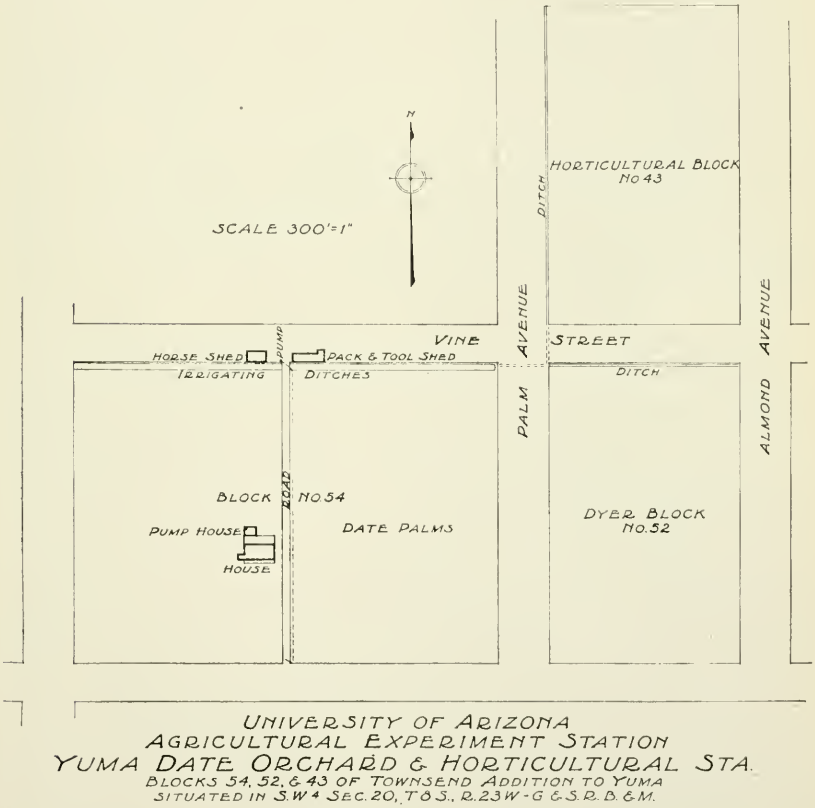


Fig. 3.—Elevation 125 feet.

River, first consisted of 7.2 acres of land, to which subsequently were added adjacent blocks containing, exclusive of intervening street ground, 6.7 acres of land, making a total of 13.9 acres. The

tract consists of blocks 54, 52 and 43 of the Townsend addition to Yuma, and is situated in the southwest corner of Section 20, Township 8 S., Range 23 W., G. & S. R. B. & M. This area has been cultivated, for the most part in horticultural crops, since the beginning of the work in 1905. About 3.5 acres are at this time occupied by date palms, but between the rows and throughout the remainder of the tract numerous agricultural and horticultural crops have been grown during the twelve years that the orchard has been in operation. The fertile, level soil of this tract has been valuable in carrying out plant breeding work, especially with wheat, during the past several years; and much of the progress made in plant breeding with alfalfa, wheat, corn, beans and sorghums, has been due to the facilities afforded by this tract. Beginning with it as a jungle of arrow weed in 1905, it has subsequently become one of the most public places in the Yuma Valley, past which nearly all rural travel passes over Warrenite roads to and from the adjacent city. There can be no doubt of the influence upon crops and agricultural methods exerted by this little farm, and in future, as in the past, it will doubtless remain useful as an experimental asset and as a means of illustrating crops and methods to those who frequently witness the work done there.

THE PRESCOTT DRY-FARM

The Prescott dry-farm consists of a diversified area of 100 acres of bench and bottom lands seven miles north of Prescott, Arizona, on the line of the S. F. P. & P. Railroad. It is defined as that portion of the S.W. ¼ of Section 31, Township 15 N., Range 1W., G. & S. R. B. & M., lying west of the right of way of the S. F. P. & P. Railroad. This tract is representative of large areas of lands lying at approximately 5,000 feet elevation in the northern part of the State. Concerning these lands, formerly used for grazing purposes only, it was desired to ascertain whether or not they could be made use of by dry-farming methods of culture. While, at first the outlook was adverse, persistent experimentation on this tract has discovered a number of quick-maturing, drought-resistant crops that mature here. With an average rainfall of 13.4 inches per annum since the beginning of operations in 1912 and with the help of dry-farming methods of culture, it has been demonstrated that quick-growing, drought-resistant crops of milo maize, feterita, and Indian corn, may be grown and put up for use of livestock which each spring is sure to need this forage to tide over the short

range. Also, consumable crops of potatoes, several varieties of beans, pumpkins, squashes and other vegetables, and certain varieties of fruits, may be grown, all of which may contribute materially to the food supply of a family. Sudan grass, both for hay and seed, has succeeded well on the summer rainfall of the Prescott dry-farm.

During the past year experimental work has been limited to

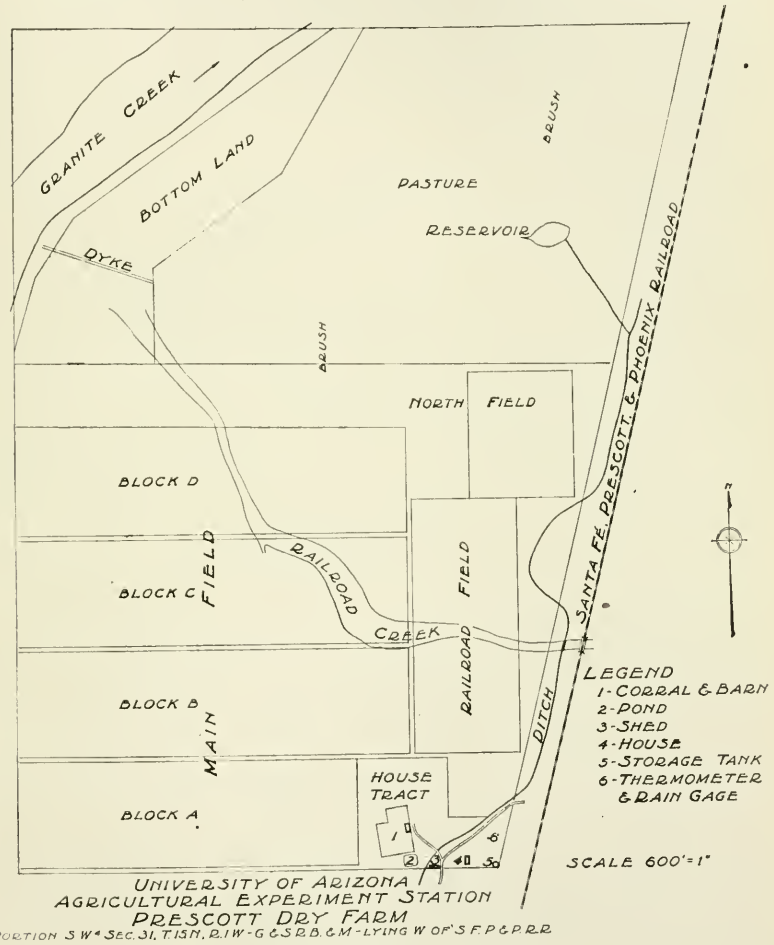


Fig. 4.—Elevation 4980 feet.

comparatively few varieties of crop plants, the main effort being concentrated on a demonstration, the object of which is to show if possible that a farmer can, with the aid of silos and livestock, make a comfortable living upon this land. These efforts have this year been fairly successful, resulting in production valued at about

$2,000 from 40 cultivated acres. It is believed that for several years to come perhaps the greatest usefulness of this tract will consist in a continuation of this home-making demonstration, under conditions formerly thought to be of value only for the grazing of range animals.

THE SULPHUR SPRING VALLEY DRY-FARM

This area, consisting of 160 acres of land in Sulphur Spring Valley at an altitude of about 4,000 feet, has been operated by the Experiment Station beginning in 1913. The tract, which is situated

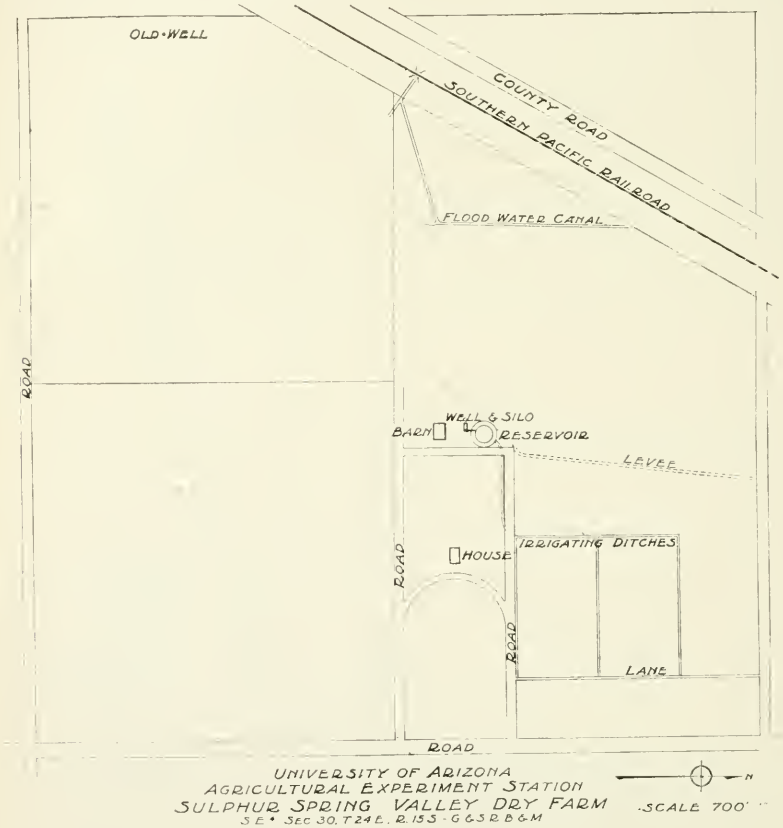


Fig. 5.—Elevation 4250 feet.

near Cochise, Arizona, on the Southern Pacific Railroad, represents considerable areas of former grazing lands in the southern valleys of the State and consists of the Southwest ¼, Section 20, Township 24 E., Range 15 S., G. & S. R. B. & M. The rainfall averages 11 inches a year, groundwater is available by pumping at 70 feet,

and occasional floodwaters from overlying watersheds may be diverted for irrigation during the summer rainy season. Rainfall conditions are on the whole less favorable than at the higher altitude of the Prescott dry-farm, and conditions are accordingly more severe for experimental work. Nevertheless in most years fair crops of kafir, club head sorghum, milo maize, feterita, and sometimes Indian corn may be grown for silage, and such crops as Sudan grass and tepary beans for forage and for human consumption. Vegetable crops and fruit trees must at this altitude be irrigated for assurance of success.

The solution of the more difficult problem of making a living from the land at this altitude probably resides in a combination of dry-farming methods of culture, of supplemental irrigation by means of pumped water to start or to save a crop, silos and livestock with which to make most effective use of the forages produced, and adjacent grazing ranges with their occasional burdens of cheap feed. Upon such a combination it is possible to demonstrate that careful farmers can make a living from the land; and the best usefulness of the Sulphur Spring Valley farm for several years to come will probably consist in handling it in such a way as to demonstrate whether or not locations of this character can be made to support those living upon them.

THE SALT RIVER VALLEY FARM

This farm, consisting of 162 acres of the Maricopa sandy loam soil of Salt River Valley, is described as the north ½ of the south ½ of Section 20, Township 1 N., Range 5 E., G. & S. R. B. & M. The tract is situated upon and between the Arizona State Highway and the Arizona Eastern Railroad, about one mile west of Mesa, Arizona. As to its irrigating water supply it is Class A land; and groundwater for pumping and domestic purposes is obtainable at 30 feet. Climatic conditions are intermediate between those of the more distinctively citrus growing sections of the Valley and the frostier levels, and can probably be used for the more frost resistant citrus varieties. This property was acquired in 1914 and has accessible to it at this time telephone service, electricity for light and power, gas, and sewerage. The shape of the tract, which is one mile long and one-quarter of a mile wide, together with its location on the Arizona Eastern Railroad and the State Highway, make of it a very public piece of property and one therefore capable of conveying a maximum amount of information to the observing public

For the past two years the work at this farm has been mainly its reclamation from infestations of bermuda, Johnson grass, and other weeds, with which it was occupied at the time of the purchase. This reclamation is now about complete and the area is ready for the installation of experimental and demonstrational work with the numerous crops that may here be exhibited.

A comprehensive and permanent plan for the improvement of the place is in process of execution. During the current year the adacent railroad right of way has been fenced and Johnson grass disposed of by means of sheep; old ditches have been plowed in and new ditches have been opened according to the plan; the land has been leveled and bordered in one-acre plots throughout most of the place; a central roadway has been developed from east to west through the farm; and particularly, a new cement headgate and ditch have been constructed from north to south through the center of the place for the double purpose of irrigating portions of the farm itself and to carry water which has right of way to lands below. Incidentally to these operations remunerative crops of wheat, cotton, corn, barley, oats, alfalfa and

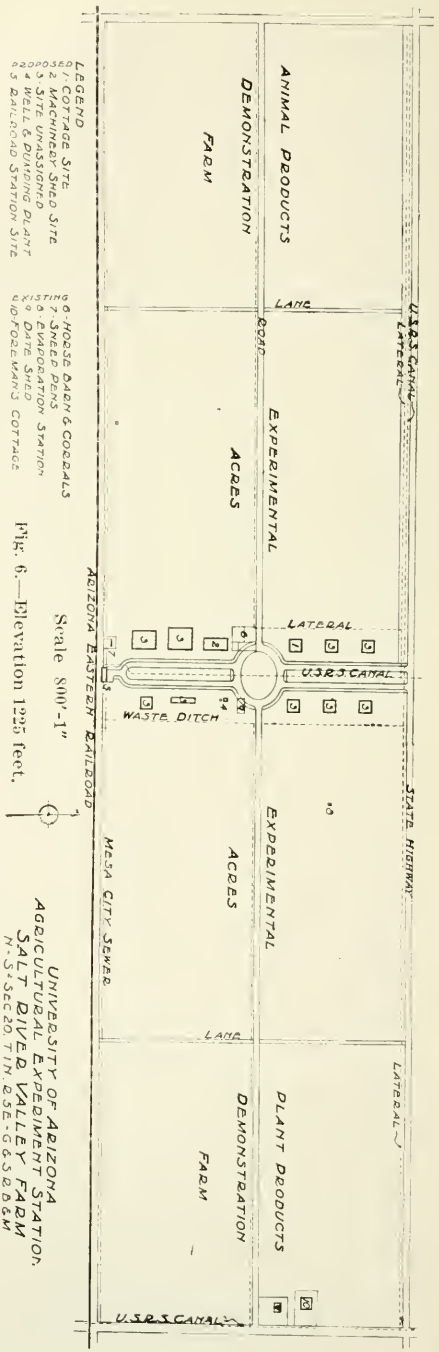


Fig. 6.—Elevation 1225 feet. Scale 800'-1"

UNIVERSITY OF ARIZONA
AGRICULTUBEAL EXPERIMENT STATION
SALT RIVER VALLEY FARM
N.½ SEC 20 T1N R5E-G&SRB&M

dwarf milo maize have been produced; and experimental crops of cowpeas, darso, field peas, flax, garbanzos, lettuce, perilla, pink beans, soy beans, sugar beets, tepary beans, and vetch have been grown. In addition, plant breeding work with alfalfa has occupied several acres of ground.

This farm, by reason of its publicity and the useful character of the work which is being done upon it, is bound to become an influential factor in the agriculture of the region. In the immediate future it is planned to develop crops of pure high-grade seed supplies of wheat, corn, milo maize, oats, barley and other crops, with a view to the needs of the farmers desiring to improve their crops thereby, and other beneficial lines of work are in prospect for this farm.

Of the usefulness and value to the agriculture of the State of this beautiful property there can be no question, and it is planned to make it a center of information and influence in the agricultural affairs of the region.

EMERGENCY WORK

Immediately following the declaration, April 6, 1917, of a state of war with Germany, an effort was made to align helpfully the activities of the Agricultural Staff in the matter of increased food production, for food conservation, and for the more effective operation of agricultural agencies.

At meetings of the Staff April 6, April 10 and April 17, ways and means of accomplishing this were discussed and plans laid for the stimulation of various agricultural activities bearing upon the food supply. Information was arranged for relating to the crops that could be grown to best advantage during the immediately ensuing summer season, and this information was published both as an Arizona Council of Defense circular and as Timely Hint No. 126 of the Experiment Station series. The suggestions made included the planting of sorghum grains April to June, inclusive; pink and tepary beans to follow winter grains; forage sorghums and Sudan grass for silage and hay; vegetable gardens and, particularly, potatoes in the northern part of the State; Indian corn both in irrigated and in dry-farming locations to be preserved as silage for the feeding of livestock the following winter when forage supplies are ordinarily deficient.

An increased number of food animals, particularly hogs, sheep and cattle, was advised, and the building and filling of silos was urged as a necessary measure in connection with the conservation of livestock.

Saving of wastes was outlined to include the canning and drying of surplus foods and vegetables; the curing of meats; and by waging war against insect pests and plant diseases.

It was pointed out that inadequately employed labor could be made more useful; that idle machinery could be kept more fully at work; and that such materials as milo maize; feterita and Kafir corn could be manufactured into cheap meals for human food, thereby releasing larger quantities of wheat to be exported for war purposes.

Helpful agencies were also discussed, particularly the land banks and other means to finance agricultural undertakings; the railroads in connection with lands along their lines; and the various public agencies available for the advice and guidance of farmers.

These suggestions, practically all of which have been followed up since they were made, have resulted in various propaganda, in several publications, and in a multitude of verbal or written items of advice to those seeking information.

One result of these discussions was the Agricultural Mobilization Conference, April 20 and 21, at the University of Arizona, which was an inspiring and useful meeting of farmers, livestock men and those less directly concerned in agriculture. This meeting was conducted primarily with reference to increased food production.

At various times the Agricultural Staff has co-operated with the Arizona State Council of Defense in the work of compiling information, of advising increased production and conservation of wastes, and in various ways collaborating with the important work of that body in connection with useful propaganda relating to food supply. While therefore primarily concerned with the discovery and dissemination of new facts in agricultural science, the Agricultural Staff has in addition during the year contributed materially to the general economic movement in support of the war.

PERSONNEL

The Agricultural Staff has suffered some changes in the course of the year, partly for military and partly for ordinary reasons. Dr.

Wallace Macfarlane, Professor of Agronomy, joined the National army in September; and A. L. Enger, Assistant Engineer, went to the Engineering corps, U. S. A., in May. The Extension Service, also, has lost Mr. W. W. Pickrell, County Agent for Pima and Pinal Counties, and Mr. T. E. Scheerer, County Agent for Yavapai County.

Other younger members of the Agricultural Staff are likely to be called upon for service later, should the war continue during the current year.

Professor John F. Nicholson went to Arkansas in February as marketing specialist for the Extension Service of that State; and, Mr. F. H. Simmons, for over twelve years foreman of the date orchard at Tempe, left us to engage in agricultural work at Santa Ana, California. Mr. Simmons is in large part responsible for the working out in a practical way of the technique of date pollination, ripening and marketing at the orchard of which he has so long and faithfully been in charge. It is with more than usual regret that we record his departure.

Mr. L. L. Bates, of the Prescott dry-farm, returned in January as foreman of the farm with which he has been identified since the beginning of operations there in 1911.

PUBLICATIONS

Publications by the Experiment Station Staff for the year, including Annual Reports, Bulletins, Timely Hints for Farmers, and scientific and popular papers, are as follows:

Bulletin 78, October 20, 1916. Relation of Weather to Crops and Varieties Adapted to Arizona Conditions.
—By Alfred J. McClatchie, J. Eliot Coit, and the Station Staff

Bulletin 79, December 1, 1916. Cold-Resistance in Spineless Cacti.
—By J. C. Th. Uphof

Bulletin 80, December 15, 1916. Certain Effects under Irrigation of Copper Compounds upon Crops. —By R. H. Forbes

Twenty-seventh Annual Report, December 31, 1916. —By the Station Staff

Timely Hints for Farmers:

No. 118. July 15, 1916. Crown Gall —By J. J. Thornber

No. 119. September 15, 1916. New Legumes for Green Manuring.
—By R. H. Forbes

No. 120. July 15, 1916. The Corn Ear Worm. —By A. W. Morrill

No. 121. December 1, 1916. Tamarisks for Southwestern Planting.
—By J. J. Thornber

No. 122. December 15, 1916. Roses for the Arizona Home.
—By J. J. Thornber

No. 123. January 1, 1917. Making Soft Cheeses on the Farm.
—By W. S. Cunningham

No. 124. February 15, 1917. Some Uses of Dynamite on the Farm.
—By H. C. Heard

No. 125. March 15, 1917. Garget or Mammitis in Cows.
—By R. H. Williams

No. 126. May 3, 1917. Recommendations on Ways and Means to Improve the Food Supply in Arizona. —By R. H. Forbes

Scientific and Technical Papers:

A State Water Code for Arizona.
Trans. Twenty-third International Irrigation Congress, 1916.
—By G. E. P. Smith

The Proposed State Water Code.
Extension Circular No. 11, November, 1916. —By G. E. P. Smith

Chapter on Agriculture in the San Simon Valley.
U. S. Geol. Survey Water Supply Paper 425A, May 7, 1917.

Cotton Pests in the Arid and Semi-Arid Southwest.
Journ. Economic Entomolgy, Vol. 10, No. 3, 1917.

Popular Articles:

A Survey of Arizona's Water Supply.
Arizona Magazine VII, May, 1917. —By G. E. P. Smith

Some Problems of the Tractor Buyer.
Southwestern Stockman-Farmer, October 27, 1917. —By G. E. P. Smith

The History of Livestock in Arizona.
Arizona Magazine, September, 1916. —By R. H. Williams

Sheep Breeding in the Southwest.
American Sheep Breeder, October, 1916. —By R. H. Williams

Breeding for the West.
Breeders' Gazette, March 1, 1917. —By R. H. Williams

Capitalizing the Range.
Breeders' Gazette, March 8, 1917. —By R. H. Williams

Alfalfa Bloat.
Hoard's Dairyman, April 6, 1917. —By R. H. Williams

Horses for the Dry-Farming Country.
Breeders' Gazette, April 19, 1917. —By R. H. Williams

A Range Problem.
Arizona Magazine, May, 1917. —By R. H. Williams

Silage in Arizona.
Rural World, June 16, 1917. —By R. H. Williams

The Future of the Range.
Agricultural Review, March, 1917. —By R. H. Forbes

PROJECTS

A restatement at this time is advisable of the projects of work being carried on by the Experiment Station inasmuch as under the pressure of war conditions it is necessary to make these projects as immediately economic in character as is practicable. Most of the activities of the Station are directly related to the big things of Southwestern agriculture—to water supply, to climatic conditions,

to livestock and farm management, to the range industry, to irrigated soils, and to major crops grown within the region.

Of necessity the work of the Station, in order to be effective, must be concentrated upon a comparatively limited number of projects at any one time inasmuch as a limited personnel cannot safely undertake too great a range of subjects for fear of ineffectively dissipating its energies.

By reason of the unusually distinct set of conditions confronting Arizona workers, there is perhaps comparatively little likelihood of duplicating the work of other stations, although there is of course excellent reasons for a selection of subjects in order to avoid duplicating the efforts of other agencies operating in the same field. Following, therefore, is a list of active projects at the present time:

1. Groundwater studies along the lower Santa Cruz river, including observations on recharge of groundwaters from floods; and fluctuations of the water table under influence of recharge and pumping.
Adams and State funds. G. E. P. Smith.

2. A study of pumping machinery to determine fundamental facts relating to the action and efficiency of irrigation pumps from the standpoint of hydraulics and of mechanics. Adams and State funds. G. E. P. Smith

3. The production by plant breeding methods of a superior variety of alfalfa free, if possible, from the hairiness and the stemmy character of Peruvian. Methods of determining the water requirements of different varieties of alfalfa; and the biological analysis of alfalfa into its hereditary units with manipulation of these units in constructive breeding, is within the scope of this study.
Adams and State funds. G. F. Freeman and W. E. Bryan.

4. The hybridization and selection for Arizona conditions of a superior grain sorghum, combining if possible the following characters,—large upright head, uniform ripening, upright stalks, dwarf habit, earliness, leafiness, drought resistance and large individual grains.
State funds. G. F. Freeman, and W. E. Bryan.

5. A physiological and biological study of Southwestern varieties of Indian corn to determine heat and drought resistant characters; and biological analysis of these corns with a view to the use of hereditary characters in constructive plant breeding operations.
Adams and State funds. G. F. Freeman, and W. E. Bryan.

6. The biological analysis of the genus *phaseolus* (common beans) and the improvement of varieties of beans by selective breeding. This project includes the improvement of tepary beans, especially well adapted to climatic conditions of the region. Adams and State funds G. F. Freeman and W. E. Bryan.

7. A study and comparison of durum, poulard and bread wheats with biological analyses, and constructive breeding operations for the purpose of developing a bread wheat which will retain its hardness under Southwestern conditions Adams and State funds. G. F. Freeman and W. E. Bryan.

8. The production by crossing, selection and inbreeding of Deglet Noor dates in order to bring them true to seed.
State funds. G. F. FREEMAN.

9. A study of date varieties established in Arizona, particularly with a view to the identification of characters most valuable in commercial dates.
State funds. S. B. JOHNSON.

10. The storage of fruits and vegetables most effectively under Arizona conditions. Hatch and State funds. S. B. JOHNSON.

11. An intensive half-acre garden study for the purpose of demonstrating the possibilities of a small garden in food production.
State funds. S. B. JOHNSON.

12. A study of the grasshopper pest to determine the eating capacity of grasshoppers in alfalfa fields, and observations on their feeding habits with reference to the use of poison baits.
Hatch fund. A. W. MORRILL.

13. A study of cotton and truck cut worms, including their life histories and habits and the methods and materials by means of which they may be controlled.
Adams and State funds. C. T. VORHIES.

14. The design, construction and operation of machines for processing dates in packing house practice. Pasteurization, incubation and artificial ripening of various varieties of dates by means of suitably constructed treatment and heating chambers is included within the limits of this project.
State funds. A. E. VINSON.

15. Alkali studies, particularly with reference to the rationale of damage caused by black alkali in the soil and means for the amelioration of the effects of this salt upon plants. Adams fund. A. E. VINSON, and C. N. CATLIN.

16. Composition of groundwaters of Arizona as determined from miscellaneous samples sent in for examination from time to time.
Hatch and State funds. A. E. VINSON, and C. N. CATLIN.

17. Economic flora of Arizona, particularly with reference to its utilization under range and forestry conditions.
Hatch and State funds. J. J. THORNBER.

18. Miscellaneous plant introductions and selections with a view to the establishment of new plant varieties adapted to Southwestern climatic conditions.
Hatch and State funds. J. J. THORNBER.

19. A continuation of studies at the Sulphur Spring Valley dry-farm for the purpose of working out a scheme of farming combining cultural methods, supplemental irrigation, hardy crops, silos, and livestock, by means of which a living can be made from the land at altitudes of 4,000 to 5,000 feet.
Hatch and State funds. R. H. FORBES, and H. C. HEARD

20. A continuation of studies at the Prescott dry-farm for the purpose of working out a scheme combining dry-farming methods of culture; hardy varieties of Indian corn, and sorghums suitable for silage; consumable crops of beans, fruits and vegetables; silos, and range livestock, by means of which a living can be made upon the land.
Hatch and State funds. R. H. FORBES, and H. C. HEARD.

21. A study of methods for the eradication of Johnson grass from an irrigated farm. Hatch and State funds. J. F. NICHOLSON, and H. C. HEARD.

22. Tests of varieties of legumes adapted to Southwestern conditions valuable for soil building purposes and for crops produced. These legumes include Canada field peas, Colorado stock peas, purple vetch, garbanzos, cow peas, soy beans, and alfalfa. Hatch and State funds. H. C. HEARD.

23. The culture and improvement by field selection of varieties of Indian corn suited to Southwestern conditions both under irrigation and dry-farming. Hatch and State funds. H. C. HEARD.

24. The culture and field management of Egyptian cotton at the Experiment Station farm in Salt River Valley. Hatch and State funds. H. C. HEARD.

25. The culture and management of winter grains, including wheat, oats and barley under irrigation at the Salt River Valley farm, and under dry-farming conditions at Cochise and Prescott, Arizona. Considerable quantities of pure seed are to be produced for distribution. Hatch and State funds. H. C. HEARD.

26. A continuation of studies in the culture and marketing of dates. Hatch and State funds. R. H. FORBES, A. E. VINSON, and S. B. JOHNSON.

27. Miscellaneous horticultural studies, including date palms, walnuts, figs, olives, peaches, plums, nectarines, apples, pears, persimmons, pomegranates and quinces, together with vegetable crops and small fruit at the Yuma date orchard near Yuma, Arizona. Hatch and State funds. R. H. FORBES, and S. B. JOHNSON.

28. Feeding of dry-farmed silage to range cattle to demonstrate the effectiveness of this ration for tiding cattle over short range. Hatch and State funds. R. H. WILLIAMS.

29. Poultry feeding experiments with reference to economical rations at a time of high prices. State funds. C. R. ADAMSON.

30. Economic combinations of high and low priced feeds for beef cattle, hogs and dairy cows. Hatch and State funds. R. H. WILLIAMS, and W. S. CUNNINGHAM.

31. Wintering over breeding ewes on an irrigated farm. Hatch and State funds. R. H. WILLIAMS, and W. S. CUNNINGHAM.

32. Meteorological observations. Hatch and State funds. C. H. CATLIN.

33. Ozonium root rot disease of cotton and other crops. Occurrence, life history and methods of control of the disease. Adams and State funds. D. C. GEORGE.

34. Gummosis of stone fruit trees. Occurrence, causes, methods of control of this disease. Hatch and State funds. D. C. GEORGE.

Co-operating in these investigations are Messrs. C. J. Wood at the Salt River Valley Farm, D. C. Aepli at the Yuma Horticultural Station, L. L. Bates at the Prescott Dry-Farm, H. R. Spaulding at the Sulphur Spring Valley Dry-Farm, G. F. Williams at the Tempe Date Orchard, and J. B. McGuffin at the University Farm near Tucson.

FINANCIAL

The finances of the Agricultural Experiment Station and of the Agricultural College as a whole continue to be reasonably adequate for the work in view. The Third State Legislature in March, 1917, made appropriations for the biennium beginning July 1, 1917, as follows:

College of Agriculture and Experiment Station	1917-18	1918-19
Instruction	$ 3,650.00 i.	$ 3,650.00 i.
Administration	7,500.00 i.r.	7,500.00 i.r.
Improvements	5,450.00 i.r.	5,450.00 i.r.
Greenhouse for agriculture		2,500.00 i.r.
Extension Service (not Smith Lever)	1,000.00 e.	1,000.00 e.
" " (with " ")	4,574.59 e.	6,004.15 e.
University of Arizona farm—Maintenance	11,850.00 i.	11,850.00 i.
" " " —Improvements	2,300.00 i.	2,300.00 i.
Dry-Farming Investigations—Maintenance	10,140.00 r.	10,140.00 r.
" " —Improvements	500.00 r.	
Plant Introduction and Breeding Investigations	3,000.00 r.	3,000.00 r.
Tempe Date Orchard—Maintenance	2,330.00 r.	1,770.00 r.
" " —Improvements	600.00 r.	600.00 r.
Underflow Investigations	2,400.00 r.	2,400.00 r.
Yuma Date Orchard and Horticultural Station—Maintenance	2,600.00 r.	2,600.00 r.
—Improvements	675.00 r.	400.00 r.
Salt River Valley Farm Fund—Maintenance	10,000.00 r.	10,000.00 r.
Agricultural Printing	4,000.00 r.i.	4,000.00 r.i.
Total	$72,569.59	$75,164.15

Those items marked *i* are intended primarily for instructional purposes; those marked *r* are intended for the research work of the station; while those marked *e* are for extension purposes.

Available resources for the year ending June 30, 1917, are as follows:

State funds as follows:

Hatch Fund from U. S. Treasury			$15,000.00
Adams Fund from U. S. Treasury			$15,000.00
Sales fund balances from 1915-16		$ 526.31	
Sales funds 1916-17 as follows			
Salt River Valley Farm	$2,997.85		
Yuma Date Orchard	905.46		
Tempe Date Orchard	1,610.46		
Prescott Dry Farm	113.95		
Sulphur Spring Valley Dry Farm	302.05		
Northern Arizona Dry Farm	127.50		
Hatch Sales	5,736.59	11,793.86	
		$12,320.17	
Less remittance to State Treasury	$ 518.98		
Balance on hand (including $374.77 carried to other statements)	2,719.77	3,238.75	9,081.42
Balance from 1915-16		$ 5,105.88	

Appropriations:			
Dry Farming Fund (Supervision)	3,000.00		
" " " (Prescott)	3,500.00		
Date Palm Orchards	3,506.25		
Yuma Horticultural Station	700.00		
Salt River Valley Farm	7,000.00		
Underflow Water Investigation	1,250.00		
Sulphur Springs Valley Dry Farm	3,000.00		
Northern Arizona Dry Farm	3,200.00		
Maintenance	5,825.04		
Plant Introduction and Breeding	3,000.00		
Printing	1,500.00	35,481.29	
Turned back to State		5,060.56	35,526.61
			$74,608.03

EXPENDITURES BY FUNDS AND SCHEDULES FOR THE YEAR ENDING JUNE 30, 1917

Abstract	State Appropriations	Sales Fund	Hatch Fund	Adams Fund	Total
Salaries	$10,684.18	$1,057.14	$9,891.38	$10,327.59	$31,960.29
Labor	8,157.95	3,345.61	2,906.24	639.89	15,049.69
Publications	1,476.65	26.71	3.55	.....	1,506.91
Postage and stationery	233.03	330.89	505.94	79.16	1,149.02
Freight and express	229.71	94.16	43.45	86.01	453.33
Heat, light, water and power	216.01	14.96	.....	.....	230.97
Chemicals and laboratory supplies	1.00	.....	255.41	57.88	314.29
Seeds, plants, and sundry supplies	1,436.78	544.76	79.79	195.13	2,256.46
Fertilizers	186.10	12.73	57.25	10.94	267.02
Feeding stuffs	1,064.95	311.07	9.00	28.63	1,413.65
Library	.....	16.87	8.75	14.22	39.84
Tools, machinery, and appliances	1,721.50	840.48	.....	1,657.19	4,219.17
Furniture and fixtures	671.10	47.65	.....	133.00	851.75
Scientific apparatus and specimens	336.79	.....	354.73	920.52	1,612.04
Livestock	1,603.44	1.90	.....	.....	1,605.34
Traveling expenses	2,348.20	593.60	473.14	519.05	3,933.99
Contingent expenses	39.02	11.15	23.35	.....	73.52
Buildings and land	5,120.20	1,831.74	388.02	330.79	7,670.75
	$35,526.61	$9,081.42	$15,000.00	$15,000.00	$74,608.03

AGRONOMY

Experimental work in Agronomy has been carried on at the Salt River Valley Farm near Mesa, the Prescott Dry Farm near Prescott, and the Sulphur Spring Valley Dry Farm near Cochise, Arizona. Demonstration work has been done on the University Farm near Tucson.

SALT RIVER VALLEY FARM

JOHNSON GRASS ERADICATION

The main project on the Salt River Valley Farm was the experiment in Johnson grass eradication, which was carried on in the same manner as last year. One hundred and twenty acres of the farm were divided into six fields containing, 40, 20, 10, 10, 20, and 20 acres, respectively.

In the first field, the south half of the east eighty acres of the farm, the Johnson grass was quite well under control by the beginning of the fiscal year, due to dry plowing in the summer of 1915. However, a number of seedlings came up from seed which had been left upon the land by the preceding infestation of Johnson grass plants. These seedlings were readily destroyed by the use of a weeder and by plowing in September, 1916, preparatory to seeding to grains in the following December. Virtually no Johnson grass was noted after the removal of the grains early in June of the present year. Plowing in August left the land sufficiently clean that it was considered advisable to seed to alfalfa, which was done early in November. The weed can easily be controlled in future by hand-digging.

The second field, which had been closely pastured by sheep since June, 1916, by the fall of that year contained few Johnson grass plants having rootstock of appreciable vigor. In November, 1916, the land was disked and seeded to barley to supply winter pasture. The number of sheep having been somewhat reduced, the growth of barley provided more than sufficient pasturage and about $640.00 worth of grain was harvested from the twenty acres. The land was plowed again in September, 1917, and at present virtually no Johnson grass is to be seen.

The third field, containing 10 acres, was in cotton in 1916 and by midsummer the old rootstocks were destroyed by cultivation. Numerous Johnson grass seedlings came up from seed introduced by the irrigation water of July and August, 1916, and by the time these plants had appeared the cotton was too large to admit of their destruction by cultivation without serious injury to the crop. Before the freezing weather of fall numerous seedlings had formed rootstocks. The land was plowed in January of this year and seeded thickly to Tepary beans for green manuring purposes. Soon after seeding to Tepary beans the weeds became quite troublesome and when the green manure was plowed under early in June quite large and vigorous rootstocks had been formed upon the Johnson grass. These rootstocks sent out new plants which necessitated some work with a weeder prior to planting to corn early in July of this year. By careful cultivation for the first few weeks after the corn was planted the Johnson grass was again brought under complete control.

Considerable work with the weeder and cultivator held the Johnson grass in check on the fourth field until it was planted to corn early in July, 1916. Further cultivation destroyed the vigor of the rootstocks by late summer of that year and since corn admits of cultivation at a later date than cotton, seedlings introduced by irrigating water were destroyed soon after their appearance. As a result the land was very clean when planted to cotton in March, 1917, and has been kept free from Johnson grass without a great deal more hoeing and cultivating than cotton ordinarily demands.

With the appearance of spring the fifth field, which was fallowed in 1916, disclosed a great number of fairly vigorous Johnson grass rootstocks. The land was plowed in August, 1916, and seeded to wheat in December. The luxuriant growth of the grain prevented the Johnson grass making much headway until after the harvest in June, 1917. Due to shortage of labor and teams it was impossible to plow this field immediately after the removal of the grain, and by the end of June the Johnson grass was again appearing in dangerous amounts. Plowing in August served materially to restrict the growth of the weed, but the field is by no means clean yet.

The sixth field has been dry fallowed since August, 1915. By June, 1916, the vigor of the Johnson grass rootstocks had been materially diminished, but a heavy rain early in September and accidental leakage of irrigating water lent new energy to the weed and

its control, until freezing weather in the fall of 1916, required considerable effort. During 1917, however, it has been quite easily kept in check and its vigor and stand were reduced until it was fairly in subjection by the end of June, 1917.

Results from various other methods of Johnson grass control have been sufficiently decisive that it is not deemed advisable to continue the dry fallowing experiment longer. The best economic

Fig. 7.—Wisconsin No. 6 Pedigreed Barley. Salt River Valley Farm.

method used on the Salt River Valley Farm has been the cultivation of summer tilled crops, the cost of growing being more than equaled by the produce. It appears preferable to hold the weed in check by means of disc and weeder until midsummer, at which time some crop which can be cultivated late in the season should be planted. A very effective and quick way to destroy Johnson grass is close grazing by sheep. Summer fallow followed by a crop of winter grains is a fairly effective method, but a heavy rain or accidental irrigation may undo a great deal of careful work. Summer plowing when the land is dry is very effective but expensive. Continuous fallow is both slow and costly, with no returns, and should be supplanted by other methods.

SMALL GRAINS

It has been considered advisable to discontinue most of the variety tests of small grains which have been carried on at the Phoenix Farm for a number of years. In attempting to standardize these crops work for the last fiscal year has been limited to the Early Baart variety of wheat, Texas Red and San Saba oats, Wisconsin No. 6, and common six-row barley. Where available, selected seed was planted under commercial conditions in order to increase the quantity of desirable seed which could be placed upon the market for the benefit of Arizona farmers.

The wheat yielded from forty-one to fifty bushels per acre and, with the high prices of the present season, returned very handsome profits. The oat yields varied from ninety-three to over one hundred bushels per acre, and the barley, which had been lightly pastured, from forty to sixty-five bushels.

A new variety known as Wisconsin No. 6 pedigreed barley was tried out during the past fiscal year with rather unsatisfactory results. A very large yield of grain was produced from this variety, but the breaking off of the heads greatly diminished the amount harvested.

LEGUMES

About twenty acres of Hairy Peruvian alfalfa and ten acres of the common strain were grown with results favoring the former.

Ten varieties of cow peas and fourteen varieties of soy beans were planted in May. These crops, which have been little grown in Arizona, gave promising results and the indications are that they will sometime become very valuable plants in the Southwest. While the available data are meagre, indications are that cow peas may be quite successfully planted at almost any time after danger of frost is over until there is barely sufficient growing season left for their maturity. Soy beans, on the other hand, should be planted on the latest date in the season which will allow them time for maturity before frost. With the larger and longer season varieties this date should be from the middle to the last of June and the earliest varieties may be planted as late as the first of August. Since the seed of this crop bids fair to become an important source of a partial substitute for linseed oil the possibilities of its culture are a matter of interest.

Among the more promising varieties of cow peas, Red Ripper, Two Crop Clay, Iron, and Clay may be mentioned. Desirable early

varieties of soy beans are Black Eyebrow and Ito San, and of the larger and later kinds Mammoth Yellow and Tarheel Black are especially promising.

Two varieties of field peas, White Canadian and Colorado Stock, were planted in late November, 1916. The plots were mowed

Fig. 8.—Texas Red Oats. Salt River Valley Farm.

in the following April and yielded 3300 and 4400 pounds of cured hay per acre, respectively. The Colorado Stock peas, in addition to yielding more hay, set a great many more blooms than the Canadian variety. This is consistent with previous observations.

An acre of garbanzos was seeded fairly thickly in November, 1916, and mowed late in the following April. A yield of two and one-half tons of cured hay per acre was obtained.

NEW CROPS

Rhodes grass, Natal grass and perilla, which are little known in Arizona, were tried out on the Salt River Valley Farm the current season with negative results in each case. Rhodes grass and Natal grass are becoming important forage crops in the southeastern parts of the United States. The seed of each failed to come up satisfactorily on the Salt River Valley Farm, however, and the growth of the few plants which did appear indicates that these crops will be unable to compete in Arizona agriculture with the forage crops now being grown.

Perilla, a crop native of Japan, is interesting as a possible source of a linseed oil substitute. The crop suffers very much from the arid atmosphere of the Salt River Valley and it was impossible to obtain a satisfactory stand.

Fig. 9.—Cowpeas, Salt River Valley Farm.

DISEASES

A fungus disease of cotton, and the lesser corn-stalk borer, both appeared on the Salt River Valley Farm this year. The former has been noticed before and does not appear to be serious. In effect it is very similar to the sore-shin noticed in upland cottons all through the cotton belt of the United States. Of this disease Professor J. G. Brown of the Department of Biology of the University says:

"Sore-shin probably is caused by other fungi besides *Rhizoctonia* and Atkinson has even found *Fusarium* present. The cotton seedlings submitted to me presented a marked constriction at and below the soil line. In these constricted places a brownish discoloration was often evident. Microscopic examination of the roots in section disclosed cankers, in places reaching through the bark and into the cortex, in other spots extending entirely through the phloem and cambium. Usually infected areas could be traced by a

brown discoloration of the cells. Such areas followed the cambium for a distance laterally, then extended along the medullary rays into the pith, or if the disease had continued longer, involved the xylem across two or more bundles. A mycelium was present in the infected areas which consisted of brown, septate hyphae quite regularly 4.5 micra to 6 micra in diameter. The hyphae passed into both cortical cells and those of the bundle. Typical spores of *Fusarium* were found loose in the cortical portion of the cankers, but these may have been produced by saprophytic forms of that fungus."

The lesser corn-stalk borer completely ruined an acre of pink beans on the farm, and greatly damaged an acre of teparies. The latter, however, recovered to some extent. The stand of Darso on one plot was seriously reduced, and about thirty acres of young milo in a neighbor's field was destroyed.

Dr. A. W. Morrill, State Entomologist, in speaking of the insect and its ravages says:

"This insect has been in the State for a number of years, but as far as I know last year is the first time when it has proven to be of any economic importance * * * Thorough cultivation of infested fields in the fall and winter and a general clean-up of the vines and stalks of susceptible plants is about the only step which can be recommended. In the East farmers are advised to make their plantings of corn, sorghum, and other crops subject to infestation as early as possible in the season before the insect has multiplied to a destructive extent. This, however, could hardly apply to our conditions where susceptible crops are planted in midsummer. The insect has been recorded as affecting the following plants: Beans, Indian corn, cowpeas, crab grass, Japanese cane, Johnson grass, milo maize, peanuts, sorghums, sugar cane and wheat. From the fact that the insect has been known to have occurred here for a number of years and has not previously been destructive there seems to be reason to hope that this is an occurrence which will not be repeated again soon."

PRESCOTT DRY-FARM

An additional ten acres were plowed on the Prescott Dry Farm in the spring of 1917, which brought its total cultivated area up to approximately sixty acres. The general cropping scheme was formulated with the idea of supplying a maximum amount of ensilage together with a reasonable quantity of hay and cash crops. The planting included only those varieties which had proven their adaptability to that region, with the exception of two new grain sorghums, Darso and African Kafir, and sweet clover.

SMALL GRAINS

A series of small grain plantings was made in the fall of 1916 at different dates from August 15th until the middle of November. In these plots Crimean wheat, Black winter emmer, fall rye, and Tennessee winter barley were used. The results from the earlier plantings of wheat and rye were very promising, while the later plantings did not do so well. The barley winter killed completely and yields from the emmer were small. Rye sown on the earlier dates in rows seven inches apart yielded 3200 pounds of hay per

Fig. 10.—Winter Rye. Prescott Dry-Farm

acre. In the plot where the rows were twenty-one inches apart, the yield was slightly less than 2000 pounds. Similar plots which were allowed to mature grain yielded fourteen, eleven, and nine bushels per acre, respectively, and in the later plantings the grain yields were as low as five and one-half bushels per acre. Wheat yields consistently ran about two bushels per acre more than rye. In no case was the grain of the highest quality.

SUDAN GRASS

About eight acres were planted to Sudan grass in May of the current year. Approximately one-half of this was cut for hay and the two cuttings yielded about two tons per acre in addition to a slight amount of pasturage. The remaining half, which was allowed

to mature, produced a very satisfactory yield of approximately 550 pounds of recleaned seed per acre.

CORN

Corn was planted on an eight acre field in which a green manuring crop of field peas was plowed under in the fall of 1916. Papago Sweet, White Hopi, Yellow Pima, Bloody Butcher and Reid's Yellow Dent were the varieties used. The results varied very greatly in the different plots. One two acre plot of Papago Sweet corn which was on particularly fertile ground yielded approximately twenty-four tons of green fodder per acre, the largest yield obtained on any of our farms this year.

Below is a table indicating results from corn plantings:

TABLE 1.—YIELDS OF CORN ON PRESCOTT DRY FARM, 1917.

Variety	Date planted	Planting implement	Yield per acre green fodder
Papago Sweet	May 15	Planter	7,299 lbs.
" "	" 20	"	8,297 "
" "	" 10	"	28,640 "
" "	" 10	Lister	49,783 "
" "	June 1	Planter	27,232 "
" "	" 1	Lister	23,023 "
Reid's Yellow Dent	May 10	Planter	5,428 "
" " "	" 10	Lister	2,960 "
" " "	June 1	Planter	6,003 "
" " "	" 1	Lister	7,224 "
Bloody Butcher	May 10	Planter	19,220 "
" "	" 10	Lister	18,787 "
" "	June 1	Planter	9,862 "
" "	" 1	Lister	8,949 "
White Hopi	May 10	Planter	11,829 "
" "	" 10	Lister	6,026 "
" "	June 1	Planter	21,930 "
" "	" 1	Lister	34,854 "
Yellow Pima	May 10	Planter	4,062 "
" "	" 10	Lister	8,045 "
" "	" 10	Planter	6,577 "
" "	" 10	Lister	7,429 "
Hickory King	May 20	Planter	5,382 "

PEAS AND BEANS

Ten acres were planted to field peas and beans. Considerable damage was done by rabbits and prairie dogs, but in spite of this both the peas and beans made a very satisfactory growth until the first of August, at which time they were attacked by a bacterial blight which ruined the peas and reduced the yield of beans to a

point well below any margin of profit. According to advices from the office of the State Entomologist this blight is due to *Pseudomonas phascoli* and the infection is carried in soil and by means of diseased seed. It is probable that this trouble is identical with a similar disease which appeared on the same land about three seasons ago, and if this supposition is correct its seriousness is manifested by the fact that the bacteria remained virulent in the soil for a period of three years, during which time no host plant specific for the germs has been grown. The following varieties of beans were used: Tepary, Lady Washington, Bates, Colorado Pinto and Hopi Lima, and the table given below includes the yields from each variety. The outlook for a remarkable yield of beans was very favorable before the blight appeared.

TABLE II.—YIELDS OF BEANS ON PRESCOTT DRY FARM, 1917.

Variety	Date planted	Implement	Yield per acre
Tepary	May 10	Planter	183 lbs.
"	" 10	Lister	55 "
"	June 16	Planter	539 "
"	" 16	Lister	447 "
Bates	May 9	Planter	220 "
"	" 9	Lister	166 "
"	June 16	Planter	300 "
Lady Washington	May 9	Planter	390 "
" "	" 9	Lister	166 "
" "	June 16	Planter	254 "
" "	" 16	Lister	221 "
Colorado Pinto	May 12	Planter	258 "
" "	" 12	Lister	181 "
" "	June 16	Planter	253 "
" "	" 16	Lister	212 "

SORGHUMS

Five sorghums were tried; namely, Dwarf White milo, feterita, darso, African Kafir, and Club-top sorghum. It was necessary to purchase seed for the latter on the open market, and unfortunately a hybridized mixture which in the current generation showed almost every type of sorghum but Club-top was secured. Yields of these sorghums are shown in Table III.

TABLE III.—YIELDS OF SORGHUMS ON PRESCOTT DRY FARM, 1917.

Variety	Date planted	Implement	Yield per acre	
			Green fodder	Heads
"Club-top"	May 20	Planter	11,159 lbs.	
"	" 10	"	8,932 "	
"	" 10	Lister	3,986 "	
"	June 1	Planter	6,154 "	
"	" 1	Lister	6,432 "	
Dwarf White milo	May 10	Planter	3,690 "	507 lbs.
" " "	" 10	Lister	3,583 "	839 "
" " "	June 1	Planter	3,536 "	1,512 "
" " "	" 1	Lister	4,402 "	2,032 "
Feterita	May 10	Planter	3,030 "	638 "
"	" 10	Lister	1,259 "	309 "
"	June 1	Planter	6,583 "	774 "
"	" 1	Lister	3,692 "	898 "
"	May 25	Planter	5,652 "	2,663 "
Dwarf Black-hulled White Kafir	May 20	Planter	8,034 "	
Dwarf Black-hulled White Kafir	" 20	"	8,281 "	
African Kafir	May 25	Planter	5,039 "	
Amber	May 20	Planter	11,061 "	

Darso, a new grain sorghum developed by the Oklahoma Station and claimed by them to show exceeding drought resistance, was tried out. Our results were very encouraging indeed, and while there has been no opportunity as yet for this Station to test the feeding value of darso, the outlook at present seems to indicate that it will soon become a favored crop for dry farming and possibly under irrigation. The season required is short, corresponding to that of feterita.

African Kafir, which previously had given favorable results on the Sulphur Spring Valley Dry Farm near Cochise, was tested on the Prescott Dry Farm with somewhat negative results.

POTATOES

Five varieties of potatoes were planted; namely, Peerless, Early Rose, White Rose, Rural New Yorker and Russet Burbank. These made an excellent growth until late summer, by which time there had been insufficient rainfall to mature as large a yield as had been expected. The results obtained are given in Table IV.

TABLE IV.—YIELDS OF POTATOES ON PRESCOTT DRY FARM, 1917

Variety	Date planted	Yield per acre
Peerless	May 1	3,623 lbs.
"	" 1	2,581 "
Rural New Yorker	May 1	920 "
" " "	"	2,259 "
Early Rose	May 1	4,122 "
" "	"	2,720 "
White Rose	May 1	1,817 "
" "	"	4,011 "
Russet Burbank	May 1	1,495 "
" "	"	1,309 "

Fig. 11.—Potatoes. Prescott Dry Farm.

SWEET CLOVER

Trial plantings of White sweet clover (*Melilotus alba*) were made late in May and late in July. A fair stand was obtained, but the growth was quite meagre. It is not improbable that the next season's growth from these plantings will be very encouraging and further trials are to be made on different planting dates.

SILOS AND ENSILAGE

A new pit silo twelve feet in diameter and thirty-five feet deep was built during the current season. The condition of the ground

was such that it was impossible to leave the sides smooth. Cement plaster was applied directly to the rough earth, however, and the resulting job is almost flawless. This clearly demonstrates the practicability of plastering pit silos even where extremely rough dirt walls are encountered. Two silos were already on the place; the first, a pit silo ten feet in diameter and thirty-two feet deep, and the second, an overground silo ten feet in diameter and twenty feet high. These three silos, with a capacity of one hundred and fifty-five tons of ensilage, were filled with crops from slightly less than thirty-five acres of land.

SULPHUR SPRING VALLEY DRY FARM

In the main, two projects have been carried on at the Sulphur Springs Valley Dry Farm near Cochise; namely, an extensive trial of dates and rates of planting, and an attempt to standardize a commercial crop rotation for that region. Results this year have been very unfavorable, since the ground was very dry from early spring until midsummer and crops planted after summer rains began were only fair.

In the first project four winter crops, Marquis wheat, Tennessee Winter barley, Texas Red oats and White sweet clover were planted at varying rates on four dates; early in September, October, November and December. Four summer crops, Mexican June corn, Club-top sorghum, Dwarf Kafir and Tepary beans were planted at varying rates early in March, April, May and June, late in July, and early in August. Due to the subnormal moisture conditions, the results are somewhat contradictory and not of very great value.

COMMERCIAL ROTATION PROJECT

Approximately forty acres of the Sulphur Spring Valley Dry Farm were divided into four fields of nearly equal size. On the first field Mexican June corn was planted early in April for ensilage. A very poor stand was obtained, the ground being so dry that it was necessary to plant too deeply. Continued drought limited the growth of the corn very materially. The average yield was only 2100 pounds of green fodder per acre.

Sudan grass was sown in March in the second field, but very few seeds came up and the crop was a failure. Tepary beans fol-

lowed and by virtue of the summer rains a yield of 133 pounds per acre was obtained.

Sonora wheat planted in December occupied the third field and the indifferent crop, yielding 290 pounds of grain per acre, was plowed under for green manuring purposes. Following the wheat, Tepary beans were planted and 121 pounds of recleaned beans per acre were obtained.

On the fourth field both Dwarf Kafir and Club-top sorghum were planted in March. A fair stand was obtained and replanting made considerable improvement. The drought resistant quality of Dwarf Kafir was quite manifest and the season's work resulted in 7350 pounds of green fodder per acre. Very little Club-top came up and that which did emerge was greatly damaged by drought. It yielded 2600 pounds of green fodder per acre.

UNIVERSITY FARM

Demonstration work rather than experimental work was conducted by the Department of Agronomy on the University Farm, located four miles north of the campus. The land was used chiefly in the production of feed for the livestock at present thereon. About forty acres are under cultivation, twenty-five of which are in alfalfa and the remainder in annual crops.

ALFALFA

Considerable of the alfalfa has been seeded for a number of years and the stand is no longer satisfactory. Various weeds are appearing in great numbers and the alfalfa growth is not at its maximum. The yield of hay from this part of the farm was approximately four tons per acre.

GRAINS

Nearly fifteen acres of the land devoted to annual crops were planted to barley in November, 1916. Seven acres of this, on a field which was first put in cultivation in June of last year, was plowed under for green manuring purposes, the growth being insufficient to justify its harvesting. The remainder yielded approximately one ton of hay per acre.

ENSILAGE CROPS

All of the fifteen acres devoted to annual crops was seeded to corn early in July of this year with the exception of a half acre which was planted to peanuts, one and a half acres on which feterita was sown, and two acres seeded to milo. The yields of corn varied from approximately three tons of green fodder per acre to nearly fifteen. The low yields were obtained upon plots seriously affected with alkali. Average corn yields of all plots were five and one-seventh tons of green fodder per acre.

In addition to the green fodder obtained approximately one ton of seed corn was selected from a plot which yielded about seventy bushels of mature corn per acre. Feterita yielded a little more than six tons of green fodder per acre and milo approximately five tons.

PEANUTS

Peanuts were not tried out in an extensive way. Red Spanish and Virginia were the two varieties planted and the results indicated that this crop is well adapted to our soil and climatic conditions.

MISCELLANEOUS

Circumstances have made it advisable to confine attention to the more immediately practicable features of agronomic experimental work rather than to the more technical operations which have a somewhat indirect application to commercial farming. The work has been hindered by an insufficient departmental force, Professor John F. Nicholson having left the service of the Experiment Station in February, 1917, and Dr. Wallace Macfarlane, who began his duties as Agronomist early in September, having been called into military service after a stay of about two weeks. This has left the Assistant Agronomist to take care of the entire work throughout most of the past year.

H. C. HEARD,
Assistant Agronomist.

BOTANY

The rainfall for the State as a whole was quite up to the average for the year ending June 30, 1917. As is usual there was a deficiency in some grazing districts. The summer rains for the year 1916 were somewhat above the average and were quite continuous from July to the middle of October. The longest period without perceptible rainfall extended from the middle of October to the latter part of December. The winter rains began late in December and were intermittent and considerably below the average. The heaviest winter rainfall took place in January, while the period from February to April was generally dry. This, together with the prevailing low temperatures, reduced greatly the growth on the desert and bunch grass lands. The perennial grasses did not begin growth in the Sulphur Spring Valley, or in the country about the Santa Rita Mountains, the Empire Ranch or Oracle until early in April, and there was almost no annual growth. This resulted in a shortage of spring feed on most of the ranges in southern Arizona.

LOSSES OF STOCK FROM POISON PLANTS

Some of the earlier growing poison plants as larkspurs and certain of the locos were making vigorous growth on the grazing ranges as early as February and March. This condition was very noticeable on the ranges about Willcox and Cochise in the Sulphur Spring Valley, Dragoon Summit, the Empire Ranch and also Oracle, Arizona. This was fully a month in advance of any considerable growth of the perennial grasses or annual growth. As is well known, grazing animals will not eat poison plants, normally, in the presence of good feed, but during famine periods they eat almost any sort of plant growth that contains succulence or nutriment. Accordingly, losses were heavier than usual from starvation and plant poisoning. Three species of larkspur and at least eight species of loco weeds occur in more or less abundance on the ranges in southern Arizona. Frequently these are met with only occasionally, but on closely grazed ranges it is possible for hungry animals to eat enough of these to result fatally. Locoed animals have been reported from many parts of the State.

On the Navajo Indian Reservation in northern Arizona, sheep, in particular, were poisoned in considerable numbers from eating

death camas. Specimens of the plants sent for examination proved to be a species of *Zygadenus*. Some sheep and a fe whorses were reported poisoned from eating lupines near Prescott. The specimens examined showed an abundance of the seed pods which are the parts of lupines that are most poisonous. At Snowflake, Shumway and Springerville, Arizona, water hemlock or water parsnip (*Cicuta occidentalis*) was found growing occasionally in irrigation ditches. At Greer, a few miles above Springerville, Arizona, it was growing in great abundance in the Little Colorado River. This species has not been reported heretofore from our State; it is one of the most deadly of our poison plants. Every effort should be made to keep irrigation ditches free from it, otherwise losses of stock are certain to occur in the irrigated valleys.

WEATHER CONDITIONS AS AFFECTING PLANT GROWTH

The winter of 1916-1917 was unusually cold throughout, though at no time did the temperatures drop extremely low. The thermometer at the University grounds registered temperatures below 32 degrees F. on 48 nights from November 8, 1916, to April 2, 1917, inclusive, or an average of one out of every three nights for this period of nearly five months. December was the coldest month and December 11th the coldest night with a minimum of 15 degrees F. There were 18 nights in December when the temperature dropped below 32 degrees F. At the University Farm in the Rillito Valley, four miles north of Tucson, the minimum temperature was 9 degrees F. As was expected, the temperatures there were generally lower and the number of nights greater when the temperature dropped below 32 degrees F., than at Tucson. A considerable amount of damage was done to tender exotic trees and shrubs throughout southern Arizona, though this was much less than that done during the winter of 1912-1913, when the temperature dropped to 6 degrees F.

The following ornamental trees and shrubs on the University grounds and in Tucson were more or less injured. The first seven of these were severely frozen back and the remaining ones were moderately to slightly injured. (1) Australian silk oak (*Grevillea robusta*); (2) flame tree (*Sterculia acerifolia*); (3) Brazilian pepper (*Schinus terebinthifolius*); (4) Satsuma orange (*Citrus sinensis*); (5) Japanese kumquat (*Citrus japonica*); (6) Burbank's spineless

cacti, several varieties, (*Opuntia sps.*); (7) Sago or fern palm (*Cycas revoluta*); (8) Pepper tree (*Schinus molle*); (9) Sonoran fan palm (*Neowashingtonia sonorae*); (10) Slender fan palm (*Neowashingtonia gracilis*); (11) Canary palm (*Phoenix canariensis*); (12) Popinac or huisache (*Acacia Farnesiana*); (13) Sweet Bay (*Laurus nobilis*); (14) Lemon verbena (*Lippia citriodora*); (15) Pitahaya (*Cereus Thurberi*); (16) Common oleander (*Nerium oleander*); (17) *Acacia retinodes.*

It will be both interesting and instructive for the prospective planter to compare the following list with the one given above. These ornamental trees and shrubs, mostly exotic, growing on the University grounds, were not injured in the least with the above temperatures. (1) Australian beefwood (*Casuarina Cunninghamiana*); (2) Bagote (*Parkinsonia aculeata*); (3) Cabbage palmetto (*Sabal palmetto*); (4) California fan palm (*Neowashingtonia filfera*); (5) California blue palm (*Erythraea armata*); (6) Chinese windmill palm (*Trachycarpus excelsa*); (7) Citranges, several varieties, (*Citrus trifoliata x sicusis*); (8) Common lavender (*Lavendula vera*); (9) Roman myrtle (*Myrtus communis*); (10) Desert gum (*Eycalyptus rudis*); (11) Forest Red gum (*Eucalyptus tereticornis*); (12) Japanese loquat (*Photinia japonica*); (13) Japanese pittosporum (*Pittosporum tobira*); (14) Weeping pittosporum (*Pittosporum phillyracoides*); (15) Evergreen tamarisk (*Tamarix articulata*); (16) Larustinus (*Viburnum tinus*); (17) Olive (*Olea europoea*); (18) Red box (*Eucalyptus polyanthema*); (19) Rosemary (*Rosmarinus officinalis*); (20) Mayten (*Maytenus boaria*); (21) Red gum (*Eucalyptus rostrata*); (22) Japanese box (*Euonymus japonicus*); (23) Japanese trifoliate orange (*Citrus trifoliata*); (24) Maypop (*Passiflora caerulea*); (25) *Chamaerops humilis.*

The species noted below with the exception of *Opuntia Ellisiana* were severely frozen back or killed outright in the introduction garden at the University Farm with a temperature of 9 degrees F. already noted.

Mayten (*Maytenus boaria*). This is a small evergreen tree hardy at the University Campus.

Agave or Century plant (*Agave americana*). These plants were frozen to the ground and some were killed. They had been growing in the garden for two years and were of robust growth with leaves 18 to 24 inches long.

Citranges (*Citrus trifoliata x sinensis*). These are hybrids between the hardy *Citrus trifoliata* and the cultivated orange,

grafted on trifoliate stock. They were four-year-old plants though small in size and had made slow growth during the past season, partly through lack of sufficient irrigation. They were killed practically to the ground. It is possible that under more favorable conditions of growth they would have withstood these freezes.

Spineless cacti, including several species. (*Opuntia sps.*). These were three-year-old plants and had made good growth during the past two years. All told, there were 150 of them and they ranged from three to four and one-half feet high. *Opuntia ficus indica* froze to the ground and most of the plants were killed. *Opunta* sp. Burbank's Special and *Opuntia fusicaulis* froze back to within 12 inches of the ground. *Opuntia castillae*, nopal de Castillae of the Mexicans, froze back to within 18 to 24 inches of the ground, leaving only the thick stumps. This plant was uninjured at the University grounds. It would thus appear that the tender, rapid-growing spineless cacti cannot be grown with any degree of safety in our valley lands, since there the cold is more severe than on the bench or mesa lands.

As compared with the above, the San Saba spineless pear, (*Opuntia Ellisiana*) was entirely uninjured with temperatures of 9 degrees F. Its growth, however, is only about two-thirds as rapid as that of the species mentioned above.

WORK IN THE PLANT INTRODUCTION GARDEN

The plants in the introduction garden at the University Farm were dug up and reset during the past winter and spring. They were removed in sections and the soil was well fertilized with barnyard manure, plowed deeply and relevelled. The new rows were set 8 and 10 feet apart, respectively, and the plants 2, 4 or 8 feet distant in the rows, according to the needs of the species. All the spineless cacti, citranges and agaves were discarded because of the severe injury from low winter temperatures. The species of tamarisks growing in the introduction plats on the University grounds were transferred to the introduction garden at the University Farm by means of planting cuttings, and the old plants were destroyed. This was due to the fact that some of the older plants were found to be infested with a scale insect.

A considerable number of new varieties of plants were set out in the introduction garden. These included plants of *Pistacia vera*, the pistasch nut of commerce, six varieties of grafted French and

English walnuts, nine varieties of Japanese persimmons, thirteen varieties of Hanson's hybrid plums, in addition to plants of Chinese jujube, Persian, Downing and Hick's everbearing mulberries, Carolina evergreen cherries, Virginia persimmons, buffalo berries, *Feijoa sellowana, Pinus halepensis, Pittosporum phillyraeoides, Photinia serrulata, Heteromeles arbutifolia*, and *Carpenteria californica.*

PLANT DISEASE INQUIRIES

An unsually large number of inquiries were received during the past year relative to plant diseases. This was due to a desire on the part of planters to increase crop yields and prevent waste as far as possible. A root-rot of the white sweet clover was sent in from the Sulphur Spring Valley for examination. Professor Brown identified this as a root-rot caused by the fungus, *Ozonium omnivorum.* Though not common in our State, this is a common root-rot of alfalfa and cotton in Texas.

Potato plants affected with early potato blight were sent in from near Willcox, Arizona. When the plants were examined the disease had progressed too far to secure practical results by spraying with Bordeaux mixture.

The well known sore-shin disease of cotton was recognized by Professor Brown on cotton seedling plants from Mesa, Arizona. This is a damping off disease of young cotton plants caused by a fungus, *Corticium vagum* var. *solani.* This was formerly known in its sterile form as a species of *Rhizoctonia*, and is a widespread disease attacking many crops.

The angular leaf spot disease of cotton was found on cotton plants growing at Mesa, Arizona. This disease is common in cotton growing countries and is not considered serious.

Tomato wilt, as usual, was bad during July and August. It was reported from many localities in southern Arizona. The common root-rot of alfalfa and deciduous trees also was serious in the southern and central parts of the state.

The dry-rot disease of the potato caused some damage at Flagstaff, Arizona. This is a serious disease in many potato growing communities. It is caused by a species of *Fusarium* which lives in the soil for several years, and hence careful crop rotation is essential in combating it. It is recommended that a five-year crop rotation be used in infected fields. The disease attacks both the tubers and the tops of growing plants; also, it causes dry-rot in potatoes

that are stored. Immersing seed potato tubers for two hours in a solution containing one ounce of 40 per cent formalin to every two gallons of water is of no avail with this disease, since the fungus occurs inside the tubers.

A serious disease of date fruits, both green and ripe, has developed at the Yuma date orchard. This has been evident for several years, though it is less troublesome during some seasons than others. At least 90 per cent of this year's fruit crop was damaged. The fruits become mummified and acquire a bitter taste, thus rendering them unfit for use. Professor Brown has been investigating this disease and will be able very soon to announce the results of his work. Three species of fungi have been found associated with this disease. It is not too much to expect that this disease can be controlled when the life histories of these fungi are known.

PUBLICATIONS

Timely Hint No. 121, Tamarisks for Southwestern Planting, treats of a group of Old World plants that are very resistant to our conditions of heat, drought and alkali. They are also tolerant to considerable cold. The plants are large shrubs or small trees and propagate readily from cuttings, requiring little attention when once established. They blossom profusely during the spring and early summer and with their foliage and flowers are very ornamental. They are excellent for windbreaks and ornamental planting in dry-farming communities. Very alkaline spots, often otherwise useless, may be set to these plants and made to produce an abundance of fuel for the home. Thus far, no soils have been found too alkaline for the successful growth of these plants. One species, *Tamarix articulata*, is evergreen and promises to be a valuable ornamental. Its growth is symmetrical and tree-like and it gives the appearance of an Arizona cypress. Already it is being planted considerably in Southern California. It cannot endure, without injury, temperatures below 10 or 12 degrees F.

Timely Hint No. 122, Roses for the Arizona Home. This was written in response to numerous inquiries on the subject of roses for Arizona conditions. The more hardy roses are discussed briefly and a list of the varieties that have been found best suited for growing under our conditions of soil and climate is given. Among these are tea roses, hybrid teas, hybrid perpetuals, dwarf ramblers, China or Bengal roses, and ever-blooming, climbing roses. Such topics

as soil requirements, when and how to plant roses, the care and pruning roses, and some common rose troubles are discussed.

During the early part of the year considerable time was spent in the preparation of a comprehensive bulletin on the shade and ornamental trees of the State. When about one-half complete this was stopped temporarily on account of work of more immediate importance, including certain emergency grazing range publications which are now well under way.

SCIENTIFIC

The writer has spent approximately one-fourth of his time during the past year in work on the herbarium of the University. This has consisted mainly in examining and identifying plant collections and supervising the mounting of these. Fully 15,000 specimens have thus been mounted and added to the plant collections during the year. With these additions the herbarium contains about 70,000 sheets. This particular phase of the work of the flora of the State has been given special attention for more than three years and is now nearing completion. Of the large plant collections that have been made during the last 16 years, for the most part by the writer, less than 4,000 specimens remain now to be worked over and mounted. It is planned to complete this work during the present year. Every effort has been made to have this collection as complete as possible so that it will be a valuable consideration in further economic and scientific work on the flora. It is almost needless to state that the University is the logical place for a collection of this kind.

Perhaps at no time in the future will it be necessary for the head of this department to give so large a part of his time to this kind of work. Unfortunately, work of this technical character cannot be delegated to others with any degree of economy or satisfaction. While this work does not lend itself directly to publication, it is, nevertheless, fundamental and must be done in advance of any serious comparative study of our flora. Once our plant collections are worked over, mounted up and assembled so as to be readily accessible, intelligent work looking towards a publication can be done on any part of our flora or on the flora as a whole.

J. J. Thornber,
Botanist.

HORTICULTURE

During the fiscal year ending July 1, 1917, the time of the Assistant Horticulturist was taken up as in previous years almost entirely with teaching work. Correspondence, a little extension work and a study of lettuce growing and sweet potato storage took up the balance. The work on lettuce culminated in the publication of Timely Hint No. 77.

LETTUCE

Work with lettuce was conducted at the Mesa Farm. An acre was planted with the objects in view: variety and strain tests, fertilizer tests and cultural tests.

The work with varieties included the New York, or Los Angeles variety obtained from ten different seed houses; Iceberg from seven different houses and forty-seven different varieties, with the results shown in Table V.

It can be seen from the table that the seed of the same variety from different seed houses give practically the same results except in the matter of germination. This emphasizes the desirability of making germination tests before planting. This was done with all varieties planted. Each package had the germination per cent marked on it and allowance made for seed of low germination per cent. The result was a very uniform planting considering the wide range of varieties. Samples testing lower than 30 per cent in a standard seed tester were not planted.

Eight plots 48x71.6 ft. or approximately 1-12 of an acre were laid out to receive different fertilizer treatment. Plot one received cotton seed meal at the rate of 650 pounds per acre, equivalent in fertilizing elements to five tons of barnyard manure. Plot 2 received cotton seed meal at the rate of 1300 pounds per acre. Plot 3 at the rate of 2600 pounds per acre. Plot 4, cotton seed meal at the rate of 650 pounds per acre and manure at the rate of five tons per acre. Plot 5, check, not fertilized. Plot 6, fertilized at the rate of five tons of manure per acre. Plot 7, at the rate of 10 tons per acre, and plot 8 at the rate of 20 tons per acre.

TABLE V.—VARIETY TESTS WITH LETTUCE.

No.	Variety	Source	Germination	Stand	Color of foliage	Notes
1	Iceberg	Germain Seed & Plant Co.	99%	Good	Light green touched with bronze	Next to the New York market this is the best variety for Arizona. Late in spring it heads better than New York and is therefore popular with gardeners during this season. The heads are generally smaller, lighter in color and the leaves are more wrinkled than New York. The head is solid and of fine texture. The touch of bronze adds to its appearance. All the lots headed well without shooting to seed.
2	Iceberg	The Wing Seed Co.	98	Good		
3	Iceberg	Aggeler & Musser Seed Co.	90	Good		
4	Iceberg	Oscar H. Will & Co.	58	Poor		
5	Iceberg	C. C. Morse & Co.	81	Good		
6	Iceberg	Northrup, King & Co.	85	Fair		
7	Brittle Ice	W. A. Burpee & Co.	100	Good	Pea green	Large, loose head of good quality. Leaves very brittle. Family use.
8	Hanson	W. A. Burpee & Co.	71	Fair	Light yellow Green	Medium sized heads of good quality. Leaves very rolled and "blistered."
9	Big Boston	Aggeler & Musser Seed Co.	81	Fair	Light blue Green	A large, firm butterhead, a sure header. The best butterhead for commercial planting.
10	Buttercup	Thorburn Seed Co.	81	Good	Yellow green	A small butterhead variety of no value under Arizona conditions.

TABLE V.—*Continued*

No.	Variety	Source	Germination	Stand	Color of foliage	Notes
11	Oakleaf	Thorburn Seed Co.	80%	Fair	Light blue Green	Small grower, very sweet, a novelty in that the leaves are shaped lke oak leaves.
12	Giant Crystal Head	Thorburn Seed Co.	92	Good	Same as Iceberg	Similar to Iceberg but not as regular a header.
13	Trocadero	Thorburn Seed Co.	23		Not planted	because of poor germination.
14	American Gathering	Thorburn Seed Co.	53	Fair	Bronze	A poor head of no value under Arizona conditions.
15	New Orchid	Thorburn Seed Co.	94	Fair	Variegated	A novelty in the color of the foliage. A late variety forming fair heads.
16	Red Romaine	Thorburn Seed Co.	72	Good	Beet red	This variety has a flaring top and readily runs to seed. Of no value.
17	Black Seeded Romaine	Thorburn Seed Co.	48	Fair	Dark green	A very late Romaine variety with a flaring top. Of no value in Arizona.
18	White Paris Cos	Vaughan Seed Store	97	Good	Blue green with a bronze touch	The best of the type but the type is not adapted to Arizona.
19	New York	Germain Seed & Plant Co.	21		Not planted	because of poor germination.
20	New York	Thorburn Seed Co.	98	Good	Dark green	A good lot. Headed regularly.
21	Wonderful (probably New York)	Germain Seed Co.	3		Not planted	because of poor germination.

TABLE V.—*Continued*

No.	Variety	Source	Germination	Stand	Color of foliage	Notes
22	New York	Wing Seed Co.	80	Good	Dark green	A good lot.
23	Henderson's New York	Currie Bros. & Co.	72	Fair	Dark green	A good lot except for weakened germination.
24	Los Angeles synonym for New York	Aggeler & Musser	83	Good	Dark green	A good lot. Identical with New York.
25	New York	Ross Bros. & Co.	68	Fair	Dark green	Mixed lot. Not up to standard.
26	New York	Peter Henderson & Co.	79	Poor	Dark green	What there was headed well and showed the usual characteristics of the variety.
27	New York	Vaughan Seed Co.	86	Good	Dark green	A good lot.
28	New York	Portland Seed Co.	67	Good	Dark green	A good lot.
29	New York	Northup, King & Co.	1		Not planted	because of poor germination.
30	New York	Germain Seed Co.	91	Good	Dark green	A good lot.
31	New York	Tucson Seed Co. (Purchased 1915)	47	Good	Dark green	A good lot.
32	Black Seeded Simpson	Wing Seed Co.	96	Good	Yellow green	A loose leaf variety, runs to seed.
33	Express Cos	Vaughan Seed Store	95	Good	Dark green	Practically the same as White Paris.
34	Balloon Cos	Thorburn Seed Co.	56	Fair	Dark green	Practically the same as White Paris Cos.
35	Golden Yellow Cos	Thorburn Seed Co.	34	Fair	Blue green	Flaring top. Of no value for Arizona.

TABLE V.—*Continued*

No.	Variety	Source	Germination	Stand	Color of foliage	Notes
36	Trianon Cos	Vaughan Seed Co.	86	Good	Dark green	Similar to White Paris Cos.
37	Giant Glazier	W. A. Burpee & Co.	85	Good	Light yellow Green	A large late crisp type of lettuce. Will probably run to seed readily.
38	Early Cabbagehead	Moore Seed Co.	52	Good	Pea green	A good early butterhead variety.
39	White Normandy Stonehead	Moore Seed Co.	76	Good	Light yellow Green	A good butterhead variety. Headed regularly.
10	Sensation	Peter Henderson & Co.	91	Good	Pea green	A good early butterhead variety.
41	Long Island	Peter Henderson & Co.	92	Good	Pea green	Another good early butterhead variety.
42	Tenderheart	Peter Henderson	18%		Not planted	because of poor germination.
43	White Summer Cabbage	Oscar H. Will & Co.	8		Not planted	because of poor germination.
44	California Giant Forcing	Moore Seed Co.	33	Fair	Blue green	Practically the same as Big Boston.
45	Summer Gem	Moore Seed Co.	24		Not planted	because of poor germination.
46	Marblehead	Aggeler & Musser Seed Co.	89	Good	Color of Iceberg	There seemed to be no difference between this variety and Iceberg.
47	Hard Head	Oscar H. Will & Co.	78	Good	Red bronze	No heads formed. Apparently a leaf lettuce.

TABLE V.—*Continued*

No.	Variety	Source	Germination	Stand	Color of foliage	Notes
48	Tomhannock	Oscar H. Will & Co.	70	Good	Bronze and green	No heads formed. The loose central leaves were green.
49	Golden Ball	Oscar H. Will & Co.	19		Not planted	because of poor germination.
50	All the Year Round	Currie Bros. & Co.	38	Fair	Light yellow Green	Heads very small but a uniform header of good quality.
51	Brown Head	Thorburn Seed Co.	95	Good	Leaves dark bronze; head green	A fairly good head was formed. Variety is of no value for Arizona.
52	Mignonette	Thorburn Seed Co.	97	Good	Dark bronze green	A poor grower of no value in Arizona.
53	Blackseed Butter	Thorburn Seed Co.	96	Good	Light yellow Green	A fair butterhead variety.
54	Crispette	Portland Seed Co.	95	Good	Color of Iceberg	Can detect no difference between this and Iceberg.
55	St. Louis Butterhead	Vaughan Seed Store	75	Good	Pea green	A fair butterhead variety. Medium to large size.
56	Unrivaled	Vaughan Seed Store	69	Fair	Dark yellow Green	Similar to Big Boston but lighter in color. Said to be a selection from Big Boston.
57	Denver Market	W. A. Burpee & Co.	79	Fair	Light yellow Green	A good quality crisp lettuce but it doesn't form as hard heads as New York.
58	Passion	Thorburn Seed Co.	20		Not planted	because of poor germination.

TABLE V.—*Continued*

No.	Variety	Source	Germination	Stand	Color of foliage	Notes
59	Maximum or Immensity	Vaughan Seed Store	96	Good	Blue green	Large, coarse butterhead variety.
60	Wayahead	Northup, King & Co.	33	Poor	Pea green	A small butterhead variety. Quality only fair.
61	Large Drumhead	C. C. Morse & Co.	97	Good	Whitish green	Large, coarse, leafy growth. Shot to seed quickly.
62	Crisp as Ice	Northup, King & Co.	6		Not planted	because of poor germination.
63	Hubbard Market	Thorburn Seed Co.	32	Fair	Pea green	Small butterhead variety of fair quality.
64	Market Gardener's Private Stock	Thorburn Seed Co.	66	Good	Pea green	A very uniform header. Heads small. A good strain.

The results of these fertilizer tests were very hard to measure. On the first four plots such an irregular stand was secured that no records were kept. The records on plots five to eight are of little value because of the many factors affecting the results. There is no definite period of maturity in lettuce. It increases in size for a long time after it might be marketed. Practically any of the soil in the Salt River Valley is strong enough to grow large-sized heads if it has time enough.

A good method of measuring the effects of the fertilizer was discovered too late to be used. Weighing a certain number of the most mature heads from each plot at regular intervals, would have given a comparison of yield as well as earliness.

The only conclusions that can be drawn from the fertilized plots are that the plot receiving the manure at the rate of 20 tons to the acre was the first to come to maturity and produced the best lettuce. The manure put some sour clover seed in the ground, but after the thinning no trouble was experienced from this.

Plots 5 to 8 were divided into thirds so that three strips 23.9 feet by 192 feet were planted in three different ways. The first strip was planted two rows on the ridge. The second strip was planted with one row on a ridge, and the third was planted level and flooded. These three ways of planting have all been used to some extent in Arizona. Of the three methods only the first two are at all satisfactory. The flooded seed had difficulty in germinating unless the ground was moist on the surface, and the plants did not make as good a growth after they got started. Planting two rows on a ridge was satisfactory, but involved more hand work in cultivation. The single-row system seems to be best adapted to growing lettuce under field conditions where the price of land does not warrant the added expense of hand cultivation.

SWEET POTATO STORAGE

The results of the preliminary tests in the storage of sweet potatoes at the Yuma Date Orchard are interesting. The potatoes were stored between layers of straw and covered with a thick layer of the same material. One pile was handled in the usual rough way and carried from the field in sacks. The other pile was carefully placed in crates; cured in a room kept at a temperature between 85° to 90° for one week, and then piled. The potatoes were taken out of storage April 18th with the following results: Pile No. 1 had in it 106 pounds of potatoes, of which about one-half was marketable. This was 38% of the 278 pounds put in the pile. The second pile contained 74 pounds of potatoes, of which 75% were marketable. This was 48% of the original 154 pounds put in the pile. Mr. Aepli in reporting on the potatoes when they came out of storage says, "It seems that every potato under two inches in diameter shriveled and every one over that size except the bruised ones kept very well." From this it can be seen that in putting sweet potatoes out of doors the dry air is sufficient to cure them and that to prevent excessive drying a layer of dry soil should be thrown over the pile after the curing had taken place. This work is to be continued during the year 1918.

S. B. JOHNSON,
Assistant Horticulturist.

THE DATE ORCHARDS

The date crops of 1915 and 1916 were especially interesting because the conditions governing them ranged from the best to the worst within our experience. The crop of 1915 was not only very heavy, some 5100 blooms at the Tempe orchard having been pollinated that year; but the nearly rainless fall season was perfect for ripening purposes. The yield of all varieties ripening at Tempe was therefore heavy, and there was almost no loss due to souring or to the fungus spot disease.

In 1916, however, the crop was light, only 2173 blooms having been pollinated, and the heavy rain of September 8, with subsequent humid weather, having resulted in very large losses by souring and fermentation of partly ripe dates. The fungus spot disease, to which the Deglet Noor is especially liable, also caused large losses this year.

As in previous years, artificial ripening processes were employed both for late varieties and to save the fruit which would otherwise spoil in wet weather. These processes consist, first, in some cases, in subjecting the sufficiently mature fruit to an atmosphere of carbon dioxide gas for 18 to 24 hours; and, second, in all cases, in subjecting the dates to certain degrees of heat for varying lengths of time. Conditions of humidity under which heating takes place have also much to do with the quality of the product. Each variety of dates seems to require a certain combination of conditions to ripen well and must therefore be individually studied. Deglet Noor, for instance, is first exposed under slight pressure to carbon dioxide, is then heated on trays in a ripening chamber at 45 to 49 degrees C. for 48 to 60 hours. All varieties are now pasteurized before packing in order to destroy eggs, larvae, and insects that may be present. This is done by heating at 65 degrees C. for two to four hours, according to size of dates.

Much experience has been gained also in packing and marketing the crop, most of which has been sold for immediate use as fresh fruit. Most varieties were packed in one-pound baskets and shipped in five or fifteen-basket crates, lined with unbleached muslin to exclude insects. Thus prepared for market the crop has been shipped successfully all over the United States and to Canada, and even as far as Denmark. One shipment was sent to San Francisco, thence to Honolulu, and back to San Francisco, before being delivered to the addressee. Nevertheless, it has been recommended that

the product be considered fresh fruit, and be consumed soon after leaving the orchard. In dry, cool weather these dates keep well, but in warm and humid weather some varieties sour and mold readily.

Semi-dry dates like the Deglet Noor were packed in tin boxes, and in that shape will last for months; while the dry or bread dates will last a long time with comparatively little care.

The prices charged for the product were reasonable—much less than could have been gotten for a market novelty, the desire being to avoid inflated estimates of the possible profits from date culture. Thus, fresh dates of good quality packed in baskets were delivered at the local express office,—five-pound crates for $1.00 and 15-pound crates for $2.50. Deglet Noors in 14-ounce tin boxes were sold three boxes for $1.00. A few special lots of dates were sold at higher prices and inferior grades for less. Following is a statement of sales for the graded crop of a few leading varieties for the two years under consideration:

DEGLET NOOR, 40 TREES

1915				1916			
47	boxes @ 40c	$ 18.80		36	boxes @ 35c	$ 12.60	
59	" 35	20.65		225	" 33 1/3	75.00	
745	" 33 1/3	248.35		1	" 30	.30	
1,318	" 30	395.40		2	" 25	.50	
163	" 20	32.60		61½	" 20	12.30	
96½	" 10	9.65		7	" 15	1.05	
				16	" 10	1.60	
2,428½		$725.45		348½		103.35	

BENT KEBALA, ONE TREE

1915				1916			
76	boxes @ 20c	$14.20		146	boxes @ 20c	$29.20	
31	" 16 2/3	5.15		47	" 16 2/3	7.82	
				23	" 10	2.30	
107		$19.35		216		$39.32	

HAYANY, 17 TREES

1915				1916			
85	boxes @ 25c	$ 21.25		93	boxes @ 25c	$ 23.25	
1,002	" 20	200.40		573	" 20	114.60	
2,785	" 16 2/3	464.15		1,128	" 16 2/3	188.00	
3	" 10	.30		7	" 15	1.05	
				2	" 10	.20	
3,875		$686.10		1,803		$327.10	

NAZL EL BACA, TWO TREES

1915			1916		
20	boxes @ 25c	$ 5.00			
114	" 16 2/3	19.00			
139	" 20	27.80			
1	" 10	.10			
274		$51.90			

RHARS, 159 TREES

1915			1916		
2,361	boxes @ 20c	$ 472.20	384	boxes @ 20c	$ 76.80
9,496	" 16 2/3	1,582.35	2,481	" 16 2/3	413.50
1,435½	" 10	143.55	994½	" 10	99.45
13,292½		$2,198.10	3,859½		$589.75

MAKTUM, THREE TREES

1915			1916		
25	lbs. @ 25c	$6.25	137	lbs. @ 20c	$27.40
24	" 20	4.80	5	" 16 2/3	.83
49	"	$11.05	142	"	$28.23

MENAKHER, ONE TREE

1915			1916		
44	lbs. @ 25c	$11.00			
73	" 20	14.60			
8	" 16 2/3	1.35			
7½	" 10	.75			
132½	"	$27.70			

ITIMA, FIVE TREES

1915			1916		
82	lbs. @ 25c	$20.50	30	lbs. @ 20c	$6.00
104	" 20	20.80			
37	" 16 2/3	6.15			
223	"	47.45			

KUSTAWI, SIX TREES

1915			1916		
25	lbs. @ 20c	$5.00	235	lbs. @ 20c	$47.00
27	" 16 2/3	4.50	53	" 16 2/3	8.83
1½	" 10	.15	4	" 10	.40
53½	"	$9.65	292	"	$56.23

It is of interest here to note the gross commercial results for the whole crop for three years, the scale of prices for the product remaining the same for that period of time:

	Blooms pollinated	Cash receipts	Average returns per bloom
Crop of 1915	5,100	$4,734.10	$ .93
Crop of 1916	2,173	1,563.79	.72
Crop of 1917	3,093	4,771.74	1.54

In 1915, with the palms blooming heavily and with a good season, good gross and average returns were secured. In 1916, with scant blooming and bad weather, low gross and average returns were received. In 1917, with a low blooming record but with perfect weather and no waste, a high gross and average return was secured.

It is also of interest to inspect the statement of results for the crops of 1915 and 1916 prepared, packed, and marketed in this manner, as given in Table VI by Mr. F. H. Simmons, foreman of the Tempe orchard.

This statement is by no means conclusive as to the relative merits of all varieties included therein. Some varieties are represented by only one or a very few trees; and others, while performing poorly at Tempe, are known to do well at lower altitudes.

Yet, with the experience of other years relative economic merits of the different varieties are to some extent indicated. For instance, Amari gave good results in 1915, its merit being that its extreme earliness gives it a market at a time when other varieties are not yet ripe. Early rains in 1916 soured the crop almost entirely.

Bent Kebala is a date of good quality, affording good income, ripening late both years, and thus escaping September rains in 1916.

Deglet Noor gave an almost perfect and very profitable crop of dates in 1915. Although these dates for Deglet Noor were distinctly second class as grown at Tempe, yet their flavor and their good keeping qualities made them desirable and readily marketable. In 1916 this variety was nearly all spoiled by the fungus spot disease, which is favored by wet weather. A few late Deglet Noors were ripened artificially and marketed.

Hayany in 1915 yielded an almost perfect crop of fine dates, which in our experience, are preferred by a majority of buyers both on account of the appearance and the quality of the fruit. In 1916 the crop was diminished considerably by souring, and fruit started to distant markets was much of it at first reported sour upon receipt. Later in the season, however, few complaints were received.

Itima marketed well in 1915, but was adversely affected by the wet weather the next year.

Kustawi did not bear much in 1915, but set a large crop in 1916 which, on account of the lateness of the variety, escaped the humid weather and ripened well.

Khardrawi, a late date of excellent quality but bearing lightly, was not injured by the wet weather.

Maktum, another late date of excellent quality but trees not bearing heavily, was not injured by September rains.

Menakher bore well in 1915, but none of the crop was saved the following year.

TABLE VI.—SUMMARY OF DATE CROPS BORNE AT THE TEMPE ORCHARD, 1915 AND 1916, BY VARIETIES

	1915			1916		
	No. of trees	Crop harvested	Cash rec'd	No. of trees	Crop harvested	Cash rec'd
Azerza	2	2	$ .35			$....
Amari	5	342½	59.40	5	17½	3.50
A'oochet	2	37	6.75	2	59	10.63
Arechti	4	148½	26.10			
Apdandon	1	21	3.90	1	34½	6.88
Ascherasi	2	6	1.15			
Amri				2	123	12.30
Bent Kebala	1	107	19.35	1	216	39.32
Boo Affar	1	29	5.30			
Beed Hammam	2	85	18.05	2	26	4.83
Bread dates		71½	7.95		30½	3.05
Burni	2	104	18.25	2	84	16.57
Berhi	4	11	1.95	4	154	29.70
Bagum Jurghi					21	3.73
Culls		813	81.30			
Deglet Noor	45		725.45	39	348½	103.35
Deglet Beida	1	24	3.30			
Doonga	1	81	6.55			
Dishtari				1	23	4.46
Gasby	1	54	9.95			
Gush	1	7	1.25	1	50	9.50
Hayany	17	3875	686.10	17	1803	686.10
Halawi	3	47	8.55	3	103	16.80
Hamraia	4	139½	22.95			
Hamraya	1	53	9.75	1	123½	23.61
Hellawee				1	16	3.20
Hellali				1	13	1.70
Halooa				1	12½	1.25
Hurshut				1	34	6.21
Itima	5	223	47.45	5	30	6.00
Iteem Joher				1	62	12.40
Karooij	1	9	1.50			
Kesba	1	3	.60	1	5	.93
Kustawi	6	53½	9.65		292	56.23
Khalt	1	5	1.00	6		
Khir	1	2	.35	1	13	2.40
Khadrawi	4	43	8.20	3	44	7.57
Koroch	2	14	2.35	2	70	12.53
Kabara(?)	1	36½	6.45	2	22	3.86
Kaiby				1	6	1.20

TABLE VI.—*Continued*

	No. of trees	Crop harvested	Cash rec'd	No. of trees	Crop harvested	Cash rec'd
Karba				1	1	.20
Khedrwee				1	9	1.56
Maktum	3	49	11.05	3	142	28.23
Menakher	1	132½	27.70			
Mixed Dates		3	.60		595	59.50
Nakelet Feraoon	1	68	13.15	1	4	.80
Nakelet el Leef	1	16	2.85	1	62	11.93
No Name	3	83	16.05		26	5.13
Nazl el Baca	2	274	51.90			
Nesheem	1	59	10.60	1	21	3.66
Oga or Saidy	8	170	34.45	6	119	20.70
Purdy Seedling					53	9.86
Rhazi	5	168	21.30	5	46	7.85
Retbet Regaia	2	85	15.45	1	11½	2.02
Remta	2	82	6.75			
Retbet Hafsia	1	40	3.20			
Rhars	162	13,292½	2,198.10	159	3859½	519.75
Roghm Gazal				1	5	.50
Seedling	6	37	6.80			
Seba Loosif	1	2	.35	1	5	1.00
Sayer	3	10	1.85	3	159	30.53
Seba Bedraa	1	28	3.55			
Safraia	4	96½	6.05	1	10	1.00
Saidy (not)				1	7	.77
Sukeri				2	7½	.25
Timdjouert (Red)	6	381½	65.10			
Timdjouert (Yellow)	3	140	25.20			
Tadala	4	337	61.15	4	86	16.30
Tennessim	4	343½	62.45			
Tafizooin	2	51½	8.40	1	70	12.60
Tazizaoat	1	43	8.05	1	50	8.86
Tentebusht	1	4	.80			
Taurarhet	1	44½	7.75			
Takadet	1	55	10.75	1	134	26.00
Totee	1	54	11.90	1	22	4.40
Tamzoohart				1	48	9.57
Toorekhet				2	25	4.70
Tozerzaid Khala				1	38	7.37
Unknown varieties					14	2.80
Zerza				1	8	1.60
Zrai				1	22	4.20
Zehedi	5	7	1.30		4	.80
15-7	1	37	6.75			
5-6	1	18	3.20			

Rhars ripened a heavy crop in 1915, nearly all of which was marketed; but in 1916 about three-fourths of the crop cracked open and soured on the trees.

Timdjouert (red and yellow) yielded fairly well in 1915, but all spoiled in September of the following year.

Takadet, a late variety, ripened its crop both years.

Dry dates in general came through the rainy season successfully.

These observations indicate that the climate of the region, even with the assurance afforded by ripening operations indoors, to a considerable extent controls the harvesting of the date crop, a fact which, however, is not in itself unusual or discouraging inasmuch as the date growing regions of the Old World are to some extent similarly affected by rains during the harvest season, especially on the Persian Gulf, where, it is stated, some years an almost complete loss of the date crop is caused by untimely rains.

At the present time cultural, packing house, and marketing experiences with date palms at the Tempe date orchard, place Hayany, an Egyptian variety, distinctly in the lead. This variety is a very heavy bearer. The fruit is large, easily picked and cheaply harvested. It ripens well on the tree and in adverse seasons lends itself readily to artificial ripening operations. The finished product presents and attractive appearance and the quality is fairly good. The American public has also expressed in a majority of cases a distinct preference for this variety.

Rhars also is a heavy bearer and the fruit is liked by many consumers. It ripens scatteringly on the tree, however, and is not easily picked. It sours very readily in wet weather.

Deglet Noor has given satisfactory results at Tempe only during the exceptionally dry and favorable autumn of 1915. It is not recommended for planting in the Salt River Valley, although undoubtedly a superior variety at lower altitudes having a longer season and a drier climate.

Other excellent varieties are represented by few trees only, some of which are still young and presumably not yet in full bearing. Commercial results with them, while interesting, are not necessarily conclusive. Table VII gives a summary of results with a selection of the most promising varieties at Tempe, giving, in addition to data already stated, average results per tree.

COLD STORAGE OF DATES

Some attention has been devoted during the year to the cold storage of fresh dates in order to prolong the marketing season for a perishable product, notice having been directed to the subject by the experience of Messrs. F. W. Butler and Son at the Ferry fruitstands in San Francisco. These gentlemen observed that dates being sold by them from day to day on the San Francisco market

TABLE VII.—SUMMARY OF TEMPE DATE ORCHARD SALES, 1915 AND 1916

Variety	1915			1916			Average value per tree	
	Trees	Pounds	Values	Trees	Pounds	Values	1915	1916
Hayany	17	3,875	$686.10	17	1,813	$327.10	$40.36	$19.24
Rhars	162	13,292	2,198.10	159	3,859	519.75	13.57	3.27
Maktum	3	49	11.05	3	142	28.23	3.68	9.41
Deglet Noor..	45		725.45	39	348	103.35	16.12	2.65
Bent Kebala..	1	107	19.35	1	216	39.32	19.35	39.32
Hamraya	1	53	9.75	1	123	23.61		
Kustawi	1	53	9.65	6	292	56.23	1.61	9.37
Sayer	3	10	1.85	3	159	30.53	.62	10.18
Takadet	1	55	10.75	1	134	26.00	10.75	26.00
Menakher ...	1	132	27.70					

TABLE VIII.—RESULTS WITH COLD STORED DATES

Stored	Examined					
Sept. 20 1916	Nov. 2 1916	Jan. 26 1917	Feb. 7 1917	Mar. 11 1917	May 2 1917	Nov. 17 1917
Rhars	Perfect condition..	Perfect condition	Perfect condition	Musty taste but no mould	Good condition	Few stale berries sugared mostly marketable
Hayany	Few sour dates	Mouldy and wet	58% spoiled			All mouldy and spoiled.
Bent Kebala			In perfect condition			Slightly mouldy and stale
Takadet ...			do.			Mouldy but sweet —unmarketable
Tenessim ...			do.			Slightly mouldy and stale
Saidy			do.			Slightly mouldy and stale
Hamraya ...			do.			Mouldy and quite stale
Not named..			do.			1 box mouldy, 1 box in good condition.
Iteem Johei			do.			Sugared—in perfect condition.
Purdy seedling.....			do.			Quite stale.

kept well in dry cold storage. Crates of different varieties of dates packed as for shipment were therefore placed in dry cold storage in Phoenix at a temperature of 36-38 degrees F. The date of storage was September 20, 1916, and the samples were examined at various times during a period of fourteen months with results indicated in Table VIII.

All the varieties tested except Hayany kept well until after holidays, and Iteem Joher, rich in sugar, kept perfectly for fourteen months. Rhars kept fairly well for this time also. These observations indicate that many varieties of dates may be harvested and held for sale as fresh fruit, thus avoiding overstocked markets at the height of the harvest season.

EVAPORATION AND COLD STORAGE

A further experiment with the Hayany crop of 1917 was conducted by evaporating several samples of fresh fruit to 90%, 80%, 70%, and 60% of fresh weight, and then putting them in dry cold storage at about 34-36 deg. F. These dates were picked October 19 and were examined January 23, 1918, in comparison with unevaporated fruit similarly kept. Table IX. gives the results of this experiment.

TABLE IX.—RESULTS WITH COLD STORED EVAPORATED DATES

Sample	Picked	Examined	Condition
Fresh fruit	Oct. 19 1917	Jan. 23 1918	Plump, moist, 94% mouldy
90% fresh wt.	"	"	Fresh, firm, 7% mouldy, flavor excellent
80% " "	"	"	Wrinkled, no mould, prime quality
70% " "	"	"	Semi-dry, no mould, superior quality
60% " "	"	"	Sticky-dry, no mould, very sweet, good quality

NOTE:—April 20,1918, after six months in cold storage, these dates were substantially in the condition described above. Occasional fruits evaporated to 90% of the original were specked with mould, but after removing these the rest of the package was edible and marketable. Those evaporated to 80% and 70% of the original weight were still in prime condition and of fair flavor. The unprocessed fruits used as a check were a mass of mould. Trial baskets removed from cold storage and exposed to warm dry air after one week are in good condition.—A. E. V.

These statements indicate that the fruit would have kept well at about 85% of its fresh weight; while at 70-80% it kept perfectly and was of superior quality after three months of storage.

ROOTING OF DATE PALM SUCKERS

A partial review of distributions to individuals of suckers from the date palm orchard indicates that nearly 95 percent of such dis-

tributions have perished, partly, without doubt, because of the sappy condition of suckers from the water-soaked Tempe Date Orchard, and partly perhaps also because of neglect on the part of some of those receiving them. Results at the Yuma Date Orchard, where some consignments of these suckers were sent were somewhat better, but yet far from satisfactory. Following these experiments, distributions of date suckers from the Tempe Date Orchard have been stopped for the present, and suckers are being rooted by the new method developed by the United States Department of Agriculture in the Coachella Valley. Three propagating houses have been constructed at the Salt River Valley Farm and the Yuma Date Orchard and additional capacity will be provided to take care of other suckers intended to be grown in Arizona. It is particularly important at this time thus to safeguard every date palm sucker of value, inasmuch as the French embargo upon further exportations of suckers from the Old World, as well as European war conditions, which obstruct importations from any part of the Old World, have thrown us entirely upon our own slender resources for the propagation of desirable varieties.

PROPAGATION OF DEGLET NOOR SEEDLINGS

Professor Freeman's experiment in fixing Deglet Noor palm seeds true to seed is being cared for at the Tempe Date Orchard. It will require some years for the first generation of seedlings to come to fruition and until then experimental work with the subject is limited simply to the culture of first generation trees. For details of this experiment see the Twenty-first Annual Report, page 384.

R. H. FORBES,
Director.

PLANT BREEDING

ALFALFA

In the alfalfa breeding work five series of plots are now under test. One of these is located within the covered garden on the University grounds, at Tucson, and the other four on the experimental farm near Mesa. In the series at Tucson a large number of individual plants are being tested as mother plants. Each individual is cut as soon as it comes into maturity, (early blooming stage), and weighed. By this means it is hoped to find high yielding strains having the power of rapid growth and quick recovery after cutting. In the 121 days, from August 20th to December 1st, a number of plants matured three cuttings, whereas, others matured only one. The majority of the plants matured two cuttings, the first being made about September 20th and the second about October 25th to November 10th.

A strain of alfalfa (No. 17) originating from a single plant selection in 1909 has been maintained and increased on account of the good yield and high quality of hay produced by it. Apparently, however, the mother plant was a hybrid, for the offspring was by no means uniform in type. It was decided therefore to make pedigree selections within this strain. Seeds from 25 selected mother plants were therefore secured and sown in plant rows at the Mesa Farm. The differences in average yield per plant for these rows are so interesting that they are given in Table X. in the order in which they occurred in the field.

Rows Nos. 444 and 462 may be noted for their high yields, whereas, rows Nos. 447 and 461 are correspondingly low in yield.

Yields for the 18 one-fourth-acre plots at the Mesa Farm which were planted in the fall of 1916 were recorded during the present crop season. Table XI. gives a summary of the results.

In the fall of 1917, 36 pedigree races in rows, each 600 feet long, were planted on the Salt River Valley Farm. This series constitutes the second elimination test of a large number of plant rows previously tested on the trial grounds at Tucson. In addition to these a series of 22 one-eleventh-acre plots were planted on the Salt River Farm. These plantings constitute a series of increase plots for testing out on a larger scale the elite pedigree races which have already withstood a first and second elimination test in rows.

TABLE X.—AVERAGE YIELD PER PLANT, PEDIGREE ALFALFA, SALT RIVER VALLEY FARM, 1917

No.	No. Plants	Cutting Aug. 17 lb.	Cutting Sept. 20 lb.	Cutting Nov. 15 lb.	Average lb.
442	155	.31	.19	..	..
452	156	.37	.44	.57	.46
451	148	.33	.45	.55	.44
450	160	.41	.51	.59	.50
449	140	.39	.48	.60	.49
448	150	.39	.51	.60	.50
447	153	.33	.42	.52	.42
446	154	.43	.52	.59	.51
445	158	.34	.51	.58	.48
444	141	.47	.52	.59	.53
443	147	.34	.45	.56	.45
441	146	.36	.56	.64	.52
440	143	.34	.54	.63	.50
464	151	.21	.31	.37	.30
463	146	.24	.48	.42	.38
462	152	.31	.57	.46	.45
461	145	.23	.40	.37	.33
460	152	.31	.52	.47	.43
459	145	.27	.44	.43	.38
458	155	.27	.41	.38	.35
457	148	.25	.44	.37	.35
456	80	.33	.48	.47	.43
Peruvian	133	.30	.45	.40	.38
455	84	.20	.32	.48	.33
454	155	.23	.39	.37	.33
453	149	.25	.47	.51	.41

TABLE XI.—FIELD PLOTS OF ALFALFA, SALT RIVER VALLEY FARM, SUMMER, 1917

No.	Variety	No. plots	Average total yield lbs. per A.
22	Arabian	3	10765
41	European	2	16223
39	Peruvian	6	14394
11	Variegated	3	13807
24	Algerian	2	15127
35	Siberian	1	9465
27	Turkestan		7723

As the productivity and hardiness of Peruvian alfalfa is becoming better known throughout the Southwest, the popularity of this variety is increasing rapidly. The true Peruvian alfalfa may be recognized by its somewhat stiff, upright habit, narrow leaves, dark purple flowers, and a marked pubescence (short fine hairs), on the upper parts of the stems and on the young leaves. Some confusion has arisen on account of there having been put on the

market a so-called smooth Peruvian alfalfa. However, that the superiority of the true Peruvian variety is now generally recognized by the public is reflected in the fact that purchasers are willing to pay approximately double the price of ordinary seed to dealers who can guarantee to furnish seeds of the true Hairy Peruvian alfalfa.

In order to meet the demand for information concerning Hairy Peruvian alfalfa this department has gathered together the results of its experiments and experience with this variety in the last eight years to be published as Timely Hints for Farmers No. 132. Those desiring copies of this publication may obtain same by addressing the Arizona Agricultural Experiment Station.

BEANS

Investigational work with beans during the past season has been confined to genetic studies. Hybrids of the third generation have now been secured and they furnish material for the biological analysis of the varieties entering these crosses whereby the genetic formulae of each are being resolved and tabulated. When the genetic formulae of agricultural varieties of plants in general can be written in much the same manner as the chemical formulae of organic compounds, the basis of a rationale for constructive plant breeding will have been laid.

Owing to the great demand for information concerning the culture and varieties of Southwestern beans and teparies, the original editions of the two publications (Bulletin No. 68, Southwestern Beans and Teparies and Timely Hint No. 92, The Tepary, A New Southwestern Legume) relating to this subject were quickly exhausted. To meet this demand Timely Hint No. 92 was revised and reprinted April 20, 1914, and later to fill the need for more detailed information Bulletin No. 68 was enlarged to include experimental and other data relative to beans and teparies, which have accrued in the last few years, and republished January 15, 1918.

The tepary bean, first introduced by the Arizona Experiment Station, has now become well established in the agricultural and seed trade. The common stock is now, however, beginning to be replaced by an improved variety (No. 17) which was produced by selective breeding by this department. Those desiring seeds of this new variety may obtain a list of the growers of the same by addressing this department.

CORN

The work with corn this year has been confined to that part of the project relating to the resistance of the pollen, to heat and dry air. Apparently varieties differ in this respect. Methods for the artificial germination of corn pollen have been successfully tested out and a beginning of systematic research is being developed on the part of the project.

The Papago sweet corn put out by this department (See Bulletin No. 75) has now found its way into the regular seed trade and is becoming popular in many parts of the Southwest. An unexpected development for this variety is its high promises as an ensilage corn in the high altitudes of northern Arizona, and in parts of the middle and eastern states where it has been tested.

DATES

The orchard of seedling Deglet Noor dates planted at the Tempe Date Garden, April 1-25, 1912, bloomed and bore fruit for the first time during the present season (1917). At this time 235 trees are alive and in a healthy growing condition. Of the 49 trees blooming, 22 were females and 27 were males; 21 females bore fruit. Careful notes were made upon these October 24th, at which time the fruits on a number of the trees were ripening. It is interesting to note that 10 of the 21 females bore fruit as light in color as the Deglet Noor female parent, whereas, the other 11 had fruits which were deep red when matured, and black when ripe. These facts offer the first step in the genetic analyses of the Deglet Noor date, for they indicate that the Deglet Noor variety is homozygous for the light colored fruit, whereas, the Deglet Noor male seedling used as a parent in this cross, had for a male parent some dark colored date. They furthermore indicate that the dark color of certain dates (Hyani, Perdy, etc.) is a unit character. As to quality of fruit, date of ripening and response to the stimulus of heat in artificial ripening, these seedlings varied widely. The quality was for the most part poor, a fact which further emphasizes the futility of attempting to start commercial date orchards from seedling trees. There were, however, one or two rather promising trees which indicate the possibility that by the time all of the 235 trees have proven their characters, an amply sufficient number may be found well worthy of selection for breeding stock in the further prosecution of this project outlined in 23rd Annual Report, p. 384.

WHEAT

The wheat work during the past year was confined to the economic phase of testing and selecting promising strains of the third and fourth generations of the wheat hybrids made in the summer of 1913, to genetic studies in wheat and to the compilation of data already secured. Two scientific articles originating from this data (G. F. Freeman, Linked Quantitative Characters in Wheat Crosses. Amer. Nat. Vol. LI. Nov., 1917, and George F. Freeman, A mechanical explation of progressive changes in the proportion of hard and soft wheat kernels. Journ. Amer. Soc. Agron. Vol. 10, No. 1) have been published. Others are in course of preparation.

In the wheat breeding work 500 plots of hybrid wheats were grown at the Yuma station. These formed the basis of further selections for planting in the fall of 1917, at which time 600 head rows, 100 pedigree increase plots and 25 one-tenth-acre plots were planted at the Yuma station. At the Mesa farm 10 one-fourth-acre and three one-half-acre plots were planted, for testing on a still larger scale, a number of promising pedigree races which had been previously grown in quantity sufficient for making milling and baking tests. These milling and baking tests were made by the milling department of the Kansas State Agricultural College and include the determination of the following characters of the wheat: Weight per bushel; percentage of flour, moisture, ash, acidity, protein and phosphorus; and of the flour, the moisture, ash, acidity, protein, wet gluten, dry gluten, phosphorus; and of the bread the following: Water, absorption, time of fermentation, maximum volume of dough, oven rise, weight and volume of loaf and color and texture of crumb.

The results obtained during the past three years from a comparative study of Arizona wheats, indicate that grain of excellent milling and baking quality can be raised on irrigated land in this state and that there are striking differences in the bread-making qualities of different varieties when grown under identical conditions.

Plate I is introduced as an example of these facts. The loaf in the center was baked from a blend of hard wheat flours grown in Kansas. Such blended flours make a larger, lighter loaf than could be obtained from the flour of any one wheat alone. The loaf at the elft was from Arizona grown Early Baart wheat produced on the Agricultural Experiment Station at Yuma in 1915. It will be noted

that this loaf is almost equal to that arising from the blended flours. The loaf at the left was produced from White Sonora wheat. This was also grown at the Yuma station in a plot adjacent to that on which the wheat giving the loaf at the right was grown. It is here introduced to show how strikingly the bread-making qualities of some varieties may differ, although grown under identical conditions. Realizing as early as 1899 that the product of the flour mills of the state could not long compete with flour imported from the hard wheat districts of the middle west and north, so long as they used locally grown White Sonora wheat, the Experiment Station began casting about for a higher grade wheat, which would yield well in Arizona. To this end a number of foreign wheats were imported and tested. As a result of these tests the best variety, Early Baart, was introduced to the farmers in 1902. During the interim before the Early Baart was widely distributed, the milling industry suffered greatly, to such an extent that several of the mills were compelled to close. Early Baart, however, proved so much superior to the old White Sonora in quality that the remaining active mills are now urging that their constituent farmers grow no other than Early Baart wheat. The superiority of the Early Baart in milling and baking qualities is clearly exhibited in plates II and III. Plate II is from the crop harvested in the spring of 1915 and Plate III from that harvested in 1916. The wheats giving rise to these loaves were grown each year on adjacent plots and were given identical treatment as to culture and irrigation. In both plates, the loaf baked from Early Baart flour is placed at the center, with the Sonora loaf at the left. On the right in Plate III is shown a loaf from Arizona grown Turkey Red wheat. This is the standard hard winter wheat of the middle plains region. Results for two years (1915 and 1916) indicate that for Arizona conditions at least the Early Baart is a better milling wheat.

TABLE XII.—YIELDS, MILLING AND BAKING TESTS OF ARIZONA GROWN WHEATS

Variety	Year grown	Yield per A. bu.	Wt. per bu. lb.	Volume of loaf	Character of crumb
Sonora	1915	51.7	62.3	1650 cc.	Fine—light
Early Baart.....	"	43.3	61.5	1690 "	" "
Turkey Red.....	"	43.2	60.0	1640 "	" "
Alaska or Mummy	"	34.3	57.5	1375 "	Coarse—heavy
Sonora	1916	39.1	63.5	1780 "	Fine—light
Early Baart.....	"	49.5	61.5	2035 "	" "
Turkey Red.....	"	43.2	62.8	1675 "	" "

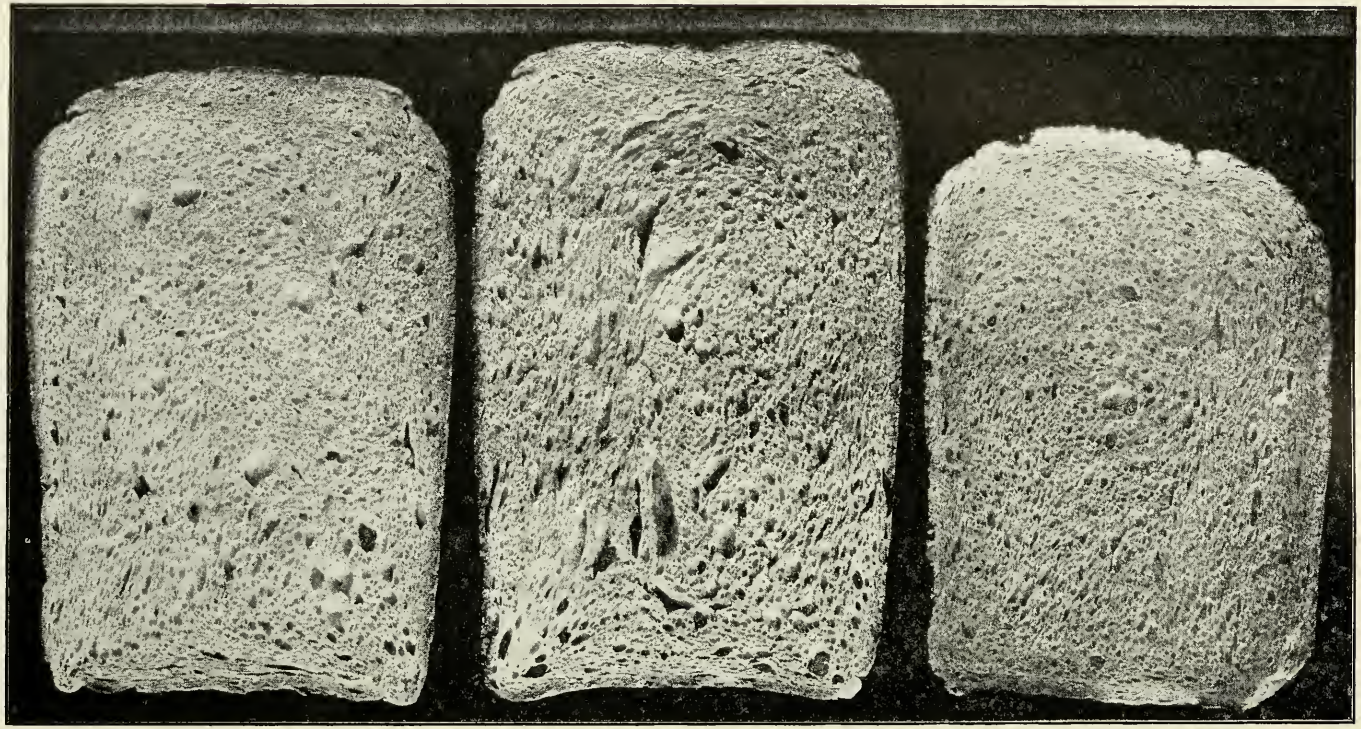


Plate I.—Comparison of bread baked from Arizona grown wheat with that from blended flour from the hard wheat districts of the Middle West

Early Baart
(Loaf volume 1810 cc.)

Hard Wheat Blend
(Loaf volume 1920 cc.)

White Sonora
(Loaf volume 1650 cc.)

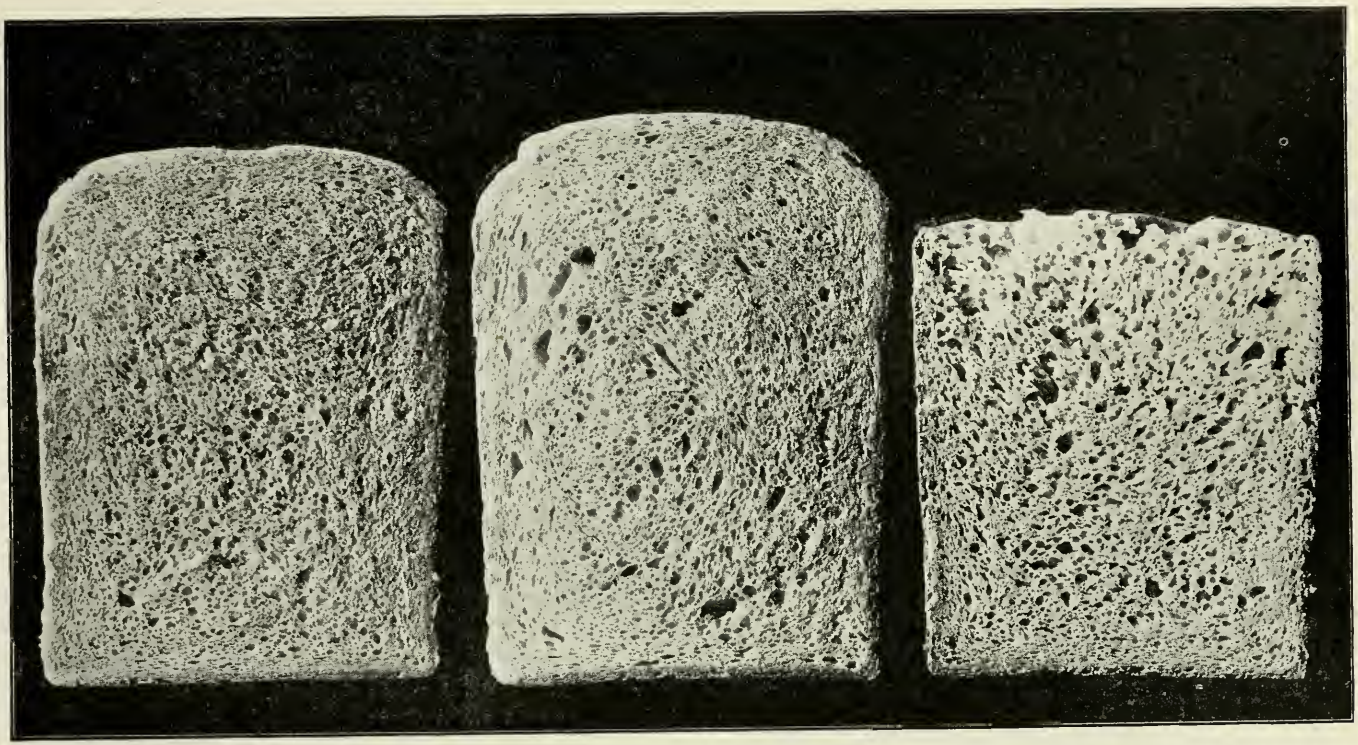


Plate II.—Bread from wheat varieties harvested from adjacent plots in 1915.

White Sonora
(Loaf volume 1650 cc.)

Early Baart
(Loaf volume 1690 cc.)

Alaska
(Loaf volume 1375 cc.)

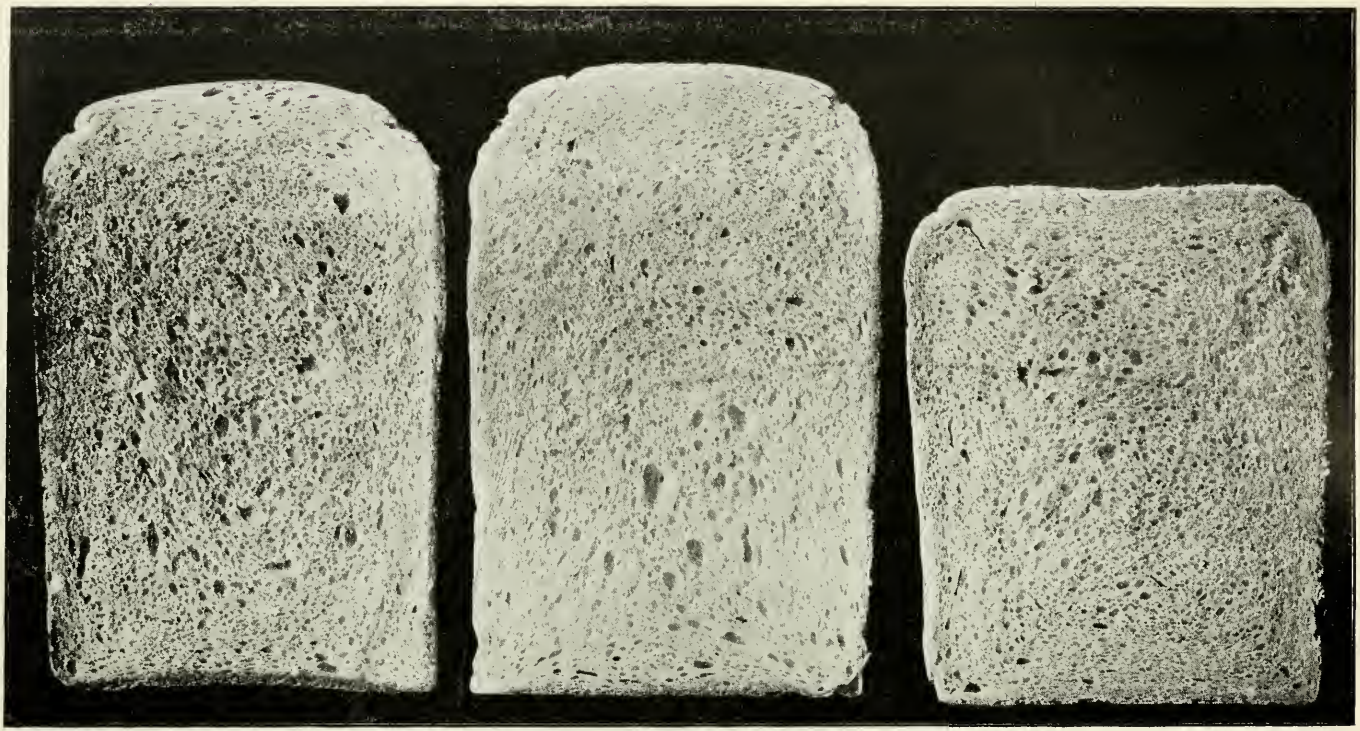


Plate III.—Bread from wheat varieties harvested from adjacent plots in 1916.

White Sonora (Loaf volume 1780 cc.) | Early Baart (Loaf volume 2035 cc.) | Turkey Red (Loaf volume 1675 cc.)

The comparative yield tests have not given finally definite results inasmuch as in 1915 the White Sonora gave the best yield, whereas, in 1916, the best yielder was Early Baart. Table XII gives a brief summary of the yields and milling and baking tests of these wheats for 1915 and 1916.

At the right in Plate II is shown a loaf of bread produced from a plot of Mummy or Alaska wheat. The yield and loaf volume of this variety are shown in Table XII. Several years ago this wheat, under the name of Alaska wheat, was introduced into Arizona and the seed sold at a high price by parties who made wonderful claims for its yielding power and milling quality. These tests show that it is in reality a practically worthless sort under Arizona conditions, and they moreover emphasize the necessity and economy of having some competent and reliable authority (such as the State Experiment Station) test all varieties of agricultural crops before they are widely sold or planted within the state.

The results of several years tests at this station have shown the decided superiority of Early Baart as a milling wheat and that in yield it is at least not inferior to other sorts. Under these circumstances the Experiment Station does not hesitate to recommend this variety where it is planned to grow a milling wheat.

Thus a superior wheat, introduced about twelve years ago by the Experiment Station, has now almost completely replaced all other varieties as a milling wheat, and has not only gone a long way toward saving the several hundred thousand dollars invested in milling machinery but has also held for the farmers a local market for one of their principal farm crops which otherwise was slipping away from them in the gradual death of the milling industry of the state.

It is not claimed that the Early Baart is a perfect wheat and that it would be impossible to improve upon it. As a matter of fact, among the several hundred hybrid wheats produced by this department there are a number which appear very promising, and it may be possible that some of them will prove superior to the Early Baart. Until, however, they have been thoroughly tried by both yield and milling tests it would be unwise to substitute any of them for a variety which has already established its value and reliability in the state.

Geo. F. Freeman,
Plant Breeder.
W. E. Bryan,
Asst. Plant Breeder.

ANIMAL HUSBANDRY

The year just closed has been one of unusual concern to Arizona stockmen. A cold winter and late spring caused considerable losses among range animals in the northern and southern counties. Summer and fall range was unusually good in Coconino, Yavapai and parts of Mojave counties. The larger part of the range producing districts received little summer, and practically no fall rains, so that the year closed with ranges in bad condition, and Gila, Pinal, Yuma, Maricopa, Cochise and Pima counties were losing many animals. Over most of the range producing states the fall range was inferior, and this closed the demand for stockers and thin cows so that few animals were sold and prices ruled lower than they were since 1913. This left the ranges much overstocked; feeds were scarce and high in price, so that losses have been unusually severe.

Except for the high mortality among shorn sheep and young lambs during the late spring sheepmen have had an unusually profitable year; ewes, lambs and wool almost doubled in value. Range was good in most of the sheep growing centers and no difficulty was encountered in marketing the surplus. The sheep and goat industries are on a sounder basis than ever before in the state and increases in the numbers of these animals can be expected if winter feed or range can be secured for them.

In irrigated districts there has been a distinct tendency to liquidate dairy cows, hogs and horses owing to the high price of long staple cotton, forage and grains. Stockmen believe that there is more money in producing crops for market than marketing them through the live stock route. They lose sight of the important consideration that live stock must ultimately be depended upon to secure a market for most agricultural products, and it is certainly a mistake at this time to go out of the dairy and hog producing business in irrigated districts.

Dry farmers are increasing their live stock holdings as a means of utilizing crops. Range stockmen are looking more and more to the production of feeds as an insurance against range shortage, and for finishing sheep and cattle for market. They have purchased

large acreages in both dry farming and irrigated districts and are using many silos to store the feed.

INVESTIGATIONS

Seven distinct lines have been followed in the investigations in animal husbandry during the past year. These were:

1. Sheep Breeding Experiments.
2. Marketing Arizona Wool.
3. Alfalfa Pasture for Hogs.
4. Feeding Dairy Cows.
5. Silage for Range Cattle.
6. Poultry Management.
7. Systems of Live Stock Farming.

SHEEP INVESTIGATIONS

Further reductions have been made in the number of cross-bred sheep on the Salt River Valley Farm, and the policy has been to maintain the best sheep in this flock and compare them with other breeds. An inventory of the sheep present July 1, 1917, is given in Table XIII.

TABLE XIII.—INVENTORY OF SHEEP JULY 1, 1917

Breed	Rams 1 yr. and over	Rams Lambs	Ewes 1 yr. and over	Ewes Lambs
Hampshire	2	2	14	6
Shropshire	2	3	7	2
Tunis	1	8	14	3
Cross-bred	5	19	46	27

Eleven Hampshire ewes and five lambs and one Shropshire ewe and a lamb were added to the flock during the year. They are a very desirable addition to the equipment of the department.

Wool Production: The sheep were shorn on March 5th and 6th, 1917, yielding a total of 526.8 pounds of wool and averaged 6.35 pounds per head. Table XIV gives the average yield of wool from the registered sheep and the main crosses.

TABLE XIV.—AVERAGE WOOL CLIP ACCORDING TO BREEDING, 1917

Hampshire	5.12 lbs.
Shropshire	5.67 lbs.
Tunis	6.22 lbs.
Hampshire crosses	6.60 lbs.
Shropshire crosses	6.71 lbs.

Breeding Records, 1916-17: In the fall of 1916 the cross-bred ewes were bred to the cross-bred bucks Nos. 504 and 549. All pure-bred ewes were mated with registered rams of the same breed. A normal lamb crop was secured and those were inspected carefully and notes taken on July 1, 1917.

The lambs sired by the cross-bred buck No. 504 and out of cross-bred ewes were of medium size, blocky, uniform and of good quality. About half of the lambs had black faces and legs, while the remainder of them varied in color from dark brown to mottled or light brown. The wool from these lambs was short but fine, soft and dense, and not more than 10% of them had inferior wool.

About half of the lambs sired by buck No. 549 had light colored faces and not more than 25% had dark points. Many were almost white in color, or light brown, and others mottled. These lambs were long in the legs, bodies and necks. They had drooping rumps and were light in the leg of mutton. Fully 60% of them were so inferior that they had to be culled out. The wool varied greatly in fineness, density and purity.

Summing up the qualities of the two rams as shown in their offspring, the lambs from ram No. 549 were longer, narrower and more rangy than those from ram No. 504. They were also less vigorous and had coarser, less dense wool, containing more kemp. The lambs from No. 504 were much more uniform than those from the other ram and there is no doubt that from the standpoint of power to transmit dark points and good wool he greatly excels the other ram. Some criticism, however, could be made of the small size of the lambs coming from this ram, but the uniformity and desirability of his lambs in other respects warrant his use another year. Buck 549 was discarded.

MARKETING WOOL

Two lots of wool were marketed to ascertain the difference between local and outside prices. One lot consisting of 743 pounds of wool was shipped from the Salt River Valley Farm and the other lot of 78 pounds from Tucson. These were consigned to commission agents in Boston and Chicago with a request that the wool be graded carefully and each grade sold on its merits. The highest prices obtainable at local points were 33 cents for the Salt River Valley wool and 21 cents for the Tucson wool.

The commission firm at Boston secured 44 cents for the Tunis wool, and 62 cents for the cross-bred wool. The Chicago agent sold

at 45 cents for the Tunis wool, 50 cents for the cross-bred, and 60 cents for the registered Hampshire and Shropshire wool. Both agents reported that the Tunis wool was highly undesirable on account of the large amount of brown hairs which it contained. These brown hairs do not take stain properly and are not suitable to make white yarn. The Boston market accepted the cross-bred wool as highly desirable, but discounted the Tunis wool 18 cents a pound below prices for good grades. The Chicago agents reported a discount of 10 cents a pound in the cross-bred and 15 cents a pound in the Tunis wool below that of Hampshire and Shropshire quality.

The increase in weight of wool between Arizona and eastern points was quite pronounced. No rain had fallen in Arizona within twenty days from the time of shipment, although the precipitation on that day was .20 inches with a trace the day before. Table XV shows the relationship of the Arizona weights and after storage in Boston until November 10, 1917.

TABLE XV.—WEIGHTS OF WOOL AT ARIZONA AND BOSTON, 1917

Name	No. of sacks	Net Ariz. weight pounds	Increase in weights		Price per lb.	Value of increase
			lbs.	%		
Tunis	1	87	5	5.8	$ .44	$ 2.20
Cross-breed .	2	358	19	5.3	.62	11.78
McElvain ...	2	219	13	5.9	.60	7.80
Longmore ...	1	79	00	0.0	.00	.00
Total.....	6	743	37			$21.78

The wool increased 37 pounds on an initial weight of 743 pounds, which is approximately 5% of an increase in weight of the wool. The value in this increase in the weight of the wool was $21.78, or 62% of the cost of marketing. This amounted to more than the freight on the wool from Arizona to Boston. Other figures secured from private shipments of wool indicate that somewhat larger increases may be secured.

It is highly interesting to note that there is much less discrimination between good and inferior wool in Arizona than at the large markets. This suggests that local dealers believe in buying wool sufficiently low to yield a profiit on almost any grade of wool which may be purchased. The total expense of marketing 743 pounds of wool was $34.90, which is approximately 4.7 cents a pound. When the increase in the weight of the wool is taken into consideration 1½ cent a pound would be sufficient to send the wool to eastern markets. In one shipment of wool it was found that the

net receipts from the commission agent was 142% greater than the highest local quotation. This suggests that persons producing as small quantities of wool as 50 pounds would profit by consigning their wool to a warehouse or commission firm.

ALFALFA PASTURE FOR HOGS

The modern method of feeding hogs in Arizona is to maintain them on good alfalfa pasture, and feed liberally on grains. Preliminary tests were conducted to ascertain the effect of feeding young pigs on alfalfa pasture alone and to learn the results of adding alfalfa pasture to an otherwise well balanced ration.

Alfalfa Pasture for Young Pigs: Two pigs 97 days old were placed on a plot of alfalfa pasture and maintained there without additional feed for eight weeks. During the first four weeks these pigs lost two and one pounds, respectively, and the next four weeks they gained eight pounds each. Over the entire eight weeks the pigs on alfalfa pasture gained only six and seven pounds, respectively, while the litter mates fed on ordinary rations made a gain of 40 pounds each. The results of this test prove that gains are extremely low with young pigs maintained on alfalfa pasture which is too coarse and bulky for them. After the pigs become older they will make slow but steady gains on alfalfa pasture alone.

Balanced Rations and Alfalfa Pasture vs. Balanced Rations in a Dry Lot: Ten registered Duroc-Jersey pigs were divided into two lots of five each. Both of these groups were fed rolled barley and skim milk, but Lot 1 was fed in a dry lot and Lot 2 was given a small amount of alfalfa pasture. Each lot was given two pounds of rolled barley and six pounds of skim milk per 100 pounds live weight. The experiment covered a period of 12 weeks and the animals were weighed once a week during this time. As the experiment advanced the amount of barley was increased to three pounds per 100 pounds live weight and the skim milk continued at the same rate.

The lot consuming alfalfa pasture made more rapid gains, but consumed 80.5 pounds more rolled barley and 108 pounds more milk. During the entire experiment the pigs in Lot 2 made more economical gains from the grain and skim milk consumed. This difference was especially pronounced at the beginning of the experiment, but towards the close there was little difference between the two lots in the amount of food required to produce 100 pounds of gain. No doubt the larger and fatter hogs made less efficient use

of the feed as they became more mature. Table XVI gives the average gain of the pigs according to four-week periods.

TABLE XVI.—GAINS OF PIGS ACCORDING TO FOUR WEEK PERIODS

Period	Lot 1		Lot 2	
	Total gain pounds	Average gain per pig pounds	Total gain pounds	Average gain per pig pounds
1st 4 weeks	81	16.20	105	21.00
2nd 4 weeks	125	25.00	145	29.00
3rd 4 weeks	167	33.40	183	36.60
Entire three periods	373	24.87	433	28.87

In every case the pigs in Lot 1 gained more slowly than those of similar breeding and individuality which were given the same food but allowed alfalfa pasture. It was only in the third period that the pigs in Lot 1 gained as much as one pound per head daily, but the animals in Lot 2 gained over one pound a day, except during the first four weeks. The animals receiving alfalfa gained 60 pounds more than those not allowed this food.

The animals in Lot 1 were distinctly unfinished in appearance, and much inferior to those receiving alfalfa pasture as judged from market and breeding standpoints. They averaged 12 pounds less in weight and there was a greater difference in attractiveness and in finish than the weight would indicate.

An average of 485 pounds of pigs were maintained on about one-eighth acre of alfalfa pasture. This is fully 2,000 pounds of pigs per acre at the outset and 5,600 at the close of the experiment. An acre of good alfalfa pasture will carry at least twenty hogs averaging 100, or 10 averaging 200 pounds. From this small plot of alfalfa and 80.5 pounds more rolled barley and 108 pounds more skim milk the hogs made 60 pounds more gain in twelve weeks than those in the dry lot. At 15 cents a pound the increased weight on the hogs would mean a yield of $9.00 for the pasture and the additional feed for the period. Deducting $2.95 for the value of the additional rolled barley and skim milk, this would mean $6.05 for one-eighth acre of pasture or $48.40 for one acre in three months. This places a high feeding value on the alfalfa pasture. After the close of the experiment the animals in the two lots were placed together and those that had been allowed alfalfa pasture made more rapid gains and appeared to be more vigorous than those on the dry lot.

ALFALFA HAY VS. ALFALFA HAY AND SILAGE FOR DAIRY COWS

During the spring of 1917 an experiment was conducted to determine the value of corn silage as a supplement for alfalfa hay when fed to dairy cows. Corn silage can be produced to good advantage on Arizona farms, and dairymen are beginning to use it quite extensively for balancing the highly nitrogenous ration supplied by alfalfa. Many dairymen want information regarding the use of silos, and it is highly important that some preliminary work be done to ascertain the desirability of adding silage to alfalfa hay.

Seven cows were used for this test and these were divided into two groups, three in one and four in the other. Since the groups could not be evenly balanced in number, quantity of milk produced, and similarity in lactation period the feeds were alternated so that each lot was given each ration the same length of time. The cows were maintained in separate corrals and an accurate quantity of hay given each lot. The corn silage was fed individually at the time of milking. An interval of ten days was allowed between each period in order to accustom the cows to a change in ration. During the first period of 21 days Lot 1 was fed a ration of 20 pounds of alfalfa hay and 35 pounds of corn silage, and Lot 2 was given 30 pounds of alfalfa hay. During the second period the rations were reversed. Table XVII gives the result of the experiment.

TABLE XVII.—AVERAGE DAILY YIELD AND COST OF RATION OF COWS FED ALFALFA HAY COMPARED WITH ALFALFA HAY AND CORN SILAGE

Ration	Average daily yield		Cost of ration per head daily cents
	Milk lbs.	Fat lbs.	
Ration 1			
Alfalfa hay 20 lbs.....			
Corn silage 35 lbs.....	24.27	.881	30
Ration 2			
Alfalfa hay 30 lbs.....	24.72	.846	30

The amount of milk and butter fat produced was practically the same for both rations. Where alfalfa is priced at $20 and corn silage at $6 per ton, the cost of the rations per day was the same for each lot. The experiment shows that 35 pounds of corn silage may replace 10 pounds of alfalfa hay in the ration. Most of the cows lost weight during the test period, but it was found that 30 pounds of alfalfa hay maintained the live weight more uniformly than the ration consisting of 20 pounds of alfalfa hay and 35 pounds of silage. The silage was dry and inferior in quality and it is believed that more favorable results would have been secured from

both the standpoint of milk production and maintaining body weight with an equal quantity of good silage.

SILAGE FOR RANGE CATTLE

The crops of corn and grain sorghums secured at the Cochise and Prescott Dry Farms were placed in silos and used for studying the suitability of silage to tide cattle over short range. In Cochise County the range was unusually short and backward during the year 1917, and the heavy covering of snow in Yavapai County produced short range, causing many animals to die from starvation.

Cochise Dry Farm: Fifteen cattle were fed silage and dry pasture to ascertain the economy of using dry farm feeds for range cattle. The animals were a mixed lot, consisting of three Hereford steers, nine months old, two Hereford heifers, two years old, one Holstein heifer, two years, one Hereford Bull, two years, and six cows of mixed breeding, ranging in age from two to ten years. There were five cows with calves at the beginning of the experiment, and another calf was born before the experiment closed. The animals averaged 564.3 pounds at the beginning of the test and after being fed an average of 98 days weighed 646.4 pounds. They consumed about 55.4 pounds of silage per day and gained from 1 to 125 pounds per head. The entire lot of 15 (omitting the calves) gained 1231 pounds, or an average of 82.1 pounds per head.

Prescott Dry Farm: In February, 1917, fourteen grade Herefords were selected to study the effect of feeding silage alone over a period of six weeks. Among the animals were seven cows so thin that a conservative stockman estimated about four of them would die before spring if left on the range. The animals were given all the silage they would consume without waste. The aim was to feed them well so that they would be in good condition rather than to learn how little silage would carry them over the winter. The animals ate about fourteen tons of silage or one ton each in six weeks. This would amount to 47.6 pounds consumed per head daily. All the cattle thrived on the silage and undoubtedly made good gains. They were strong at the close of the experiment and withstood shipping a considerable distance to spring range. During the summer they proved to be good rustlers and gave every indication of having completely recovered.

The results of the two tests give conclusive proof that silage is a good feed for cattle when the range is inferior. The succulent and nutritive qualities of the silage not only keep the animals alive, but it gives weak, hungry cows a new strength to hunt for food.

The cows and young stock did unusually well after being turned out on the range and all except those with calves were much fatter and more vigorous than similar animals left on the range.

Since there are large areas in dry farming and overflow districts suitable for growing crops for silage these experiments suggest that stockmen should put forth every possible effort to secure good land and raise crops which may be fed the animals during short range.

POULTRY

In the years 1916-17 four breeds of chickens were continued from the previous year. These were the S. C. W. Leghorns, S. C. R. I. Reds, W. Plymouth Rocks, and Black Langshans. They were used chiefly for class purposes, with an effort being made in the spring of 1917 to rear enough new stock to make the plant self-supporting.

The plan for 1917-18 includes the moving of part of the poultry plant to a new location just south of the present site in order to make room for the new observatory.

A pen of ten hens with pullet records averaging 230 eggs will be added to the present stock of Leghorns. From this pen it is planned to develop a flock of Leghorns of high egg production, gradually discarding all hens that have records less than 150 eggs per year.

INSTRUCTION AND EXECUTIVE WORK

Much time has been devoted to the general work of the department such as supervision of the live stock, planning new equipment, purchasing new animals, judging live stock at fairs, addressing meetings, correspondence, and personal conferences with stockmen. The number of students taking work in animal husbandry has increased over past years. Fifty articles have been published in technical journals and local periodicals regarding live stock.

The department has had supervision of the official testing of the registered cows of various pure bred associations. A number of very creditable seven day official records have been secured with Holstein Friesian cows owned by prominent breeders in the State. Several Jersey as well as Holstein cows have been under semi-official tests for a year, but not many have completed their records. The cow, Josephine Arizona Maid 164449, gave 13,414.9 pounds of milk, 406.7 pounds of butter fat and 508.38 pounds of butter in 365 days. This cow is owned by the University and she is the first one tested in the State to be accepted by any pure bred association for the year-long test.

The Holstein Friesian herd has been increased very materially by the purchase of a herd sire, five cows, five heifers and two calves. These animals replaced some of the grade cows which have been retained during the past five years. Table XVIII gives the yield of cows in the herd during the past year.

TABLE XVIII.—YIELDS OF DAIRY COWS AT THE UNIVERSITY FARM, 1916-17

Name of cow	Breed	Days dry before calving	Days in milk	Yield in lbs.		Aver. % butterfat
				Milk	Butter-fat	
Josephine Arizona Maid.	Holstein Friesian	76	444	14,447.4	432.2	2.99
Miss Columbia Girl.....	Jersey	0	299	3,342.3	231.8	6.93
Childeberte.....	"	87	272	4,885.1	291.0	6.63
Princess of Chewawbeek	"	100	363	6,721.2	358.9	5.34
Gipsy Draconis.....	"	34	287	5,797.7	281.2	4.85
Blanco.....	Grade Holstein	36	374	7,742.7	274.8	3.55
Mollie.....	" "	42	312	9,350.3	344.0	3.67
Exception II.....	Ayrshire	65	311	6,921.0	261.9	3.78
Pedro.....	Jersey	49	275	7,242.9	382.4	5.28
*Sheppardess.....	Grade Holstein	105	409	13,371.9	439.3	3.19
*Nettie.....	" "	54	277	9,770.6	410.2	4.19
*Missouri.....	" "	68	233	6,554.5	273.8	4.16
Average for herd.....		59.7	321.3	8,012.3	331.8	4.14

*Sold before finishing their milking period.

The Duroc-Jersey herd of hogs has been increased by the addition of two sows and a boar. It has been the policy of the department to keep nothing but registered animals of superior quality. To this end, all of the grade cows have been discarded. Owing to the limited amount of land available for raising crops it is thought best to select a few of the more important breeds and confine our efforts to them rather than to maintain a large number of breeds. Holstein Friesian, Jersey and Hereford cattle; Rambouillet, Hampshire and Shropshire sheep, and Duroc-Jersey and Poland-China pigs should be the first breeds to be developed. It is hoped that during the next year a good foundation flock of Rambouillet sheep and herd of Poland-China pigs may be secured. Another urgent necessity is the purchase of two Jersey females. With the present increase in the Holstein cattle and Duroc-Jersey hogs more uniform animals are available for investigation and instruction.

R. H. WILLIAMS,
Animal Husbandman.
W. S. CUNNINGHAM,
Assistant Animal Husbandman.

ENTOMOLOGY

During the past season the writer has considered that grasshopper control was the most important single problem which could be taken up as a matter of demonstration and direct aid in the conservation of important crops. The matter of grasshopper control has been disposed of for the most part as an experimental project by numerous investigations which have been conducted in various parts of the country during the past few years. However, there is a diversity in the details of the recommendations which have been published which show that we still lack important information in certain respects concerning the subject. In connection with demonstration work against grasshoppers in the Salt River Valley during the past season problems were presented which lead to a series of observations and tests which are of considerable local importance. The differential grasshopper (*Melanoplus differentialis*), the most destructive species in Arizona, is the one which was the subject of the investigation.

The formula for poisoned bait which is now most generally recommended by entomologists consists in a mixture of 25 pounds of bran, 2 quarts of molasses, 1 pound of Paris green, 3 to 6 finely chopped lemons or oranges and water to make a crumbly mash. The more important experiments conducted by the writer concern the matter of modifications of this formula with the view to reducing its cost and possibly increasing its effectiveness. Miscellaneous observations were made in connection with these experiments.

In many sections of southern Arizona cull canteloupes can be obtained by farmers without expense and the experiments referred to above have shown that canteloupe can be substituted for the lemons in the usual grasshopper bait formula. One pound of finely ground canteloupe may be substituted for six lemons. The experiments have further shown that with the differential grasshopper in the adult stage the molasses may be omitted without interfering with the results, also that in the place of 25 pounds of bran a half and half mixture of bran and sawdust may be substituted. These changes in the grasshopper bait formula represent a substantial decrease in the cost of grasshopper bait. A long series of experiments was first conducted on a small scale and the baits made with the substitutions noted were afterward tried out on tracts of land

varying from five to fifteen acres. Additional field tests will be necessary before the new formulae can be recommended for use against other species of grasshoppers in Arizona or against the immature stages of the differential grasshopper.

Miscellaneous observations made in connection with these experiments with poisoned baits concern the time of day when the grasshoppers feed most actively, the distance grasshoppers travel after eating a fatal dose of the bait and the amount of alfalfa which adult differential grasshoppers consume per day. The observations in regard to the time of day when the grasshoppers eat most actively were not conclusive, but from the records it appears that there is no advantage in spreading the bait late in the afternoon or very early in the morning, as has been generally supposed. Out of 3382 observations made between 3 and 6:45 P. M. it was found that 40.4 percent of the feeding records were between 3 and 3:45, 30.3 percent between 4 and 4:45, 17.6 percent between 5 and 5:45 and 9.5 percent between 6 and 6:45. These observations will be continued in order that the question in regard to the time of day when the bait can best be scattered may be definitely determined. In order to appreciate fully the effects of poisoned baits it is necessary to know how far the grasshoppers may travel after eating a fatal dose of the poison. The observations made show that poisoned grasshoppers very rarely traveled as far as 70 yards and that under ordinary conditions few traveled further than 25 yards from the place where a fatal dose of the poison is eaten.

The observations made in regard to the amount of alfalfa which grasshoppers may consume have been found to be very effective in demonstration work. The figures obtained refer to the differential grasshopper. It was found that one adult grasshopper per square yard may destroy the equivalent of three pounds of alfalfa hay per acre per day. In a forty-acre field a moderate infestation averaging 16 2-3 grasshoppers per square yard may destroy the equivalent of one ton of alfalfa hay per day. Grasshopper infestations have frequently been noted averaging between 25 and 50 grasshoppers per square yard. It is obvious to a grower to whom these calculations are presented that the expense of poisoning with one of the poisoned baits is exceedingly small in proportion to the damage done by the insects.

A. W. Morrill,
Consulting Entomologist.

CHEMISTRY

During the year the chemists have accomplished the usual amount of analytical work, mostly of soils and irrigating water, for the farmers of the State. Research work has been restricted to the study of alkali, both in the field and in the laboratory by means of the auxograph. In this connection a large number of graphs have been made showing the influence of alkali and of soil solutions on the swelling of colloids. During the summer months we were forced to discontinue this line of work because of the disturbing effect of high temperatures. The annual analyses of the Salton Sea Water, made in co-operation with the Carnegie Desert Laboratory, and incorporated in the annual report of this department for several years past, have been discontinued, because it was believed that the chief facts to be learned from the work had been discovered. Only occasional analyses of the water will be made as the sea continues to dry up. Much work was done on perfecting apparatus for pasteurizing and ripening dates, requiring the services of the assistant chemist at the Tempe Date Orchard for several weeks. Instruction and laboratory practice in soils have been given in the College of Agriculture, and much time has been devoted by the chemist to matters of curriculum and registration of agricultural students.

THE TEMPE DRAINAGE DITCH

In the Twenty-seventh Annual Report a series of six monthly analyses of the water from the new Tempe Drainage Ditch was tabulated. Eleven additional analyses are now available and are presented in the following table, together with those previously reported:

TABLE XIX.—MONTHLY VARIATION IN COMPOSITION OF WATER FROM THE TEMPE DRAINAGE DITCH, PARTS PER 100,000—(BY C. N. CATLIN)

Date	Total Solids	Chlorides as NaCl	Hardness (permanent) $CaSO_4$	Hardness (temporary $Ca(HCO_3)_2$	Alkalinity Na_2CO_3	SO_4	CaO	MgO
1916								
June 25	1665.2	1170	....	....	....	.....	....	....
July 13	1359.0	994	107.4	....	....	172.58	97.64	65.2
Sept. 10	599.4	432	27.2	67.2	....	64.76	14.2	25.2
Oct. 10	418.0	303	13.0	66.4	....	.....	....	....
Nov. 10	346.4	220	7.6	60.3	....	30.49	12.6	17.57
Dec. 8	312.6	228	5.4	64.0	....	33.78	14.6	15.75
1917								
Jan. 7	322.4	227	6.5	55.5	....	Str.	Mod. Str.	Mod. Str.
Feb. 10	312.0	216	3.2	64.0	....	"	"	" "
Mar. 9	241.0	163	....	58.5	3.4	"	"	" "
Apr. 10	308.0	222	7.6	66.8	....	"	Slight	" "
May 10	298.6	217	7.6	62.7	....	"	"	" "
June 10	309.2	209	10.8	65.2	....	"	"	" "
July 19	351.0	228	6.5	66.0	....	"	Mod.	Mod.
Sept. 15	423.6	298	32.6	61.5	....	"	Str.	Mod. Str.
Oct. 14	225.2	145	Neutral	65.6	....	Mod. Str.	Mod.	" "
Nov. 10	303.6	205	4.9	131.2	.....	Str.	Mod. Str.	Mod.
Dec. 10	292.4	168	....	122.1	11.87	Mod.	Mod.	Slight

Str.—Strong. Mod.—Moderate. Mod. Str.—Moderately strong.

The ditch was completed early in 1917, thus the water for some months has not been affected in composition by the drainage of new areas. All samples have been taken from near the outlet end of the ditch. The season has been very dry and, consequently, the composition has been changed but little by the runoff of meteoric water diluting the seepage; nevertheless, great fluctuations in composition are noticeable. March 9 the water, which had hitherto been hard, was alkaline, containing 3.4 parts per 100,000 of black alkali; but the following month, April 10, it was again found to be as hard as it had been the previous November. The analysis made in February seems to indicate that the permanent hardness of the water was decreasing at that time. During the summer months the hardness remained fairly constant, but increased three or four-fold in September, then became neutral in October and again strongly black alkaline in December, which is the last analysis available.

The total solids dissolved in the water and the chlorides show similar fluctuations. September 15 both total solids and chloride reached a maximum, but dropped abruptly to about one-half that amount in October. This period of high solids and chlorides was

accompanied by very high permanent hardness. In November and December the temporary hardness ("lime") increased to double the average for the other months of the year, which had been nearly uniform.

Fluctuations during 1916, when the total solids were decreasing rapidly, were explained, apparently, by the opening of new drainage areas as the work on the ditch progressed. The present fluctuations are less easily explained but are probably due to changes in the amount of seepage from various areas according to the amount of irrigation, and also to overflow reaching the ditch which would tend to dilute the usual seepage flow. At no time has the drainage water been entirely satisfactory for irrigating purposes on account of its high salt content. At times when the salt is excessive, as was the case in September, the water should not be applied to agricultural lands. The high black alkalinity in December would be dangerous if long continued, but the usual gypsum content of the water would serve to neutralize the occasional black alkaline flows. It is possible that a correlation between the districts receiving heavy irrigation and the character of the drainage ditch water could be worked out for the purpose of avoiding the use of excessively saline seepage water on the Indian Reservation lands below, that are being irrigated with this water. A simple volumetric test for chlorides is available and should be applied at frequent intervals by some person in the immediate vicinity. Waters above the average in salinity should be allowed to waste.

NATIVE FERTILIZER MATERIALS

The prevailing high prices of fertilizer materials, especially of nitrogen and potassium, has stimulated the search for these substances in the State. The deposits of bat guano have been drawn upon quite heavily for exportation. The discovery of nitrate of soda or Chili saltpetre in some of the rocks of the State has awakened much interest. The chemist visited one of these deposits near San Simon and secured samples for analysis. The rock, which is a rhyolitic tufa, is often covered with incrustations one-half inch thick, more or less, of nearly pure nitre where overhanging ledges protect it from the weather. The rock itself shows a few tenths percent of nitrate of soda, but occasionally very thin seams of the nearly pure salt occur. A tunnel driven ten feet into the ledge did not develop richer material. Recently a sample of similarly incrusted rock has been sent in from another part of the State, but

its origin has not been learned. A soil from the Casa Grande district sent in to be tested for alkali showed nearly ten percent of nitrate of soda. The sample was probably a surface incrustation and did not represent the soil to any appreciable depth. This material could be used to advantage as a fertilizer on lands in the neighborhood that are poorly supplied with nitrogen.

Several samples of saline materials and water from a barren oil well have been submitted to be tested for potash. In every case qualitative tests showed so little potassium that quantitative determinations were not made. Mesquite and brush ashes, and ashes from incinerators at the military camps have caused some public interest as possible sources of fertilizer. While these materials will seldom bear transportation charges to the fertilizer works, they often can be used locally with profit. Caution should be exercised, however, not to apply wood ashes to soils that tend to be black alkaline.

UNUSUAL FEEDING STUFFS

In co-operation with other departments several analyses of unusual feeding stuffs have been made. The results are shown in the following table:

TABLE XX.—COMPOSITION OF UNUSUAL ARIZONA FEEDING STUFFS

Feeding stuff	Water	Ash	Crude protein	Crude fiber	Ether extract (fat)	Carbohydrates
Yucca No. 1	72.1	1.55	2.09	4.50	0.43	19.33
Yucca No. 2	63.5	3.34	1.12	7.15	0.34	24.55
Sword beans	9.14	4.05	27.05	9.34	4.38	45.59
Alfalfa hay No. 1	6.73	8.42	16.21	29.52	2.61	36.51
" " No. 2	4.53	8.42	14.89	29.86	2.33	39.97
Alfalfa straw, Mesa	3.46	8.26	8.95	41.46	1.87	36.00
" " Yuma	4.79	5.01	6.44	49.48	1.13	33.15
Tepary bean hay No. 1	10.22	13.29	19.95	17.71	2.94	35.89
" " " No. 2	9.80	13.70	21.54	17.61	3.04	34.31
Sorghum refuse	9.38	4.57	2.62	32.98	1.39	49.06
Milo heads ground No. 1	6.19	4.67	8.99	7.64	3.30	69.21
Milo heads ground No. 2	8.55	4.13	11.46	6.77	3.11	65.98
Milo heads chopped No. 1	8.23	4.07	11.63	6.83	2.96	66.28
Milo heads chopped No. 2	8.65	4.76	9.09	7.60	3.02	66.87
Bran, Phoenix Mills	7.94	4.98	16.65	6.82	4.63	58.98
" Minnesota Red			15.19			
" Tucson Mills			18.50			
Cotton stalk hurds			9.96			
Shallu whole grain			10.32			

Yucca (*Yucca elata*) No. 1 was young growth from which the leaves had been removed, leaving only the leaf bases; No. 2 was somewhat older material. Sample No. 1 contained .19 percent of saponin in the fresh material, and Nd. 2 contained .21 percent. determined by precipitation with baryta water. No injurious effects were observed when this material was fed *ad libitum.*

Sword beans (*Canavalia ensiformis*) were grown and used for feed in Salt River Valley. They are said to yield well. Care should be used in feeding these beans, since they are sometimes poisonous.

The alfalfa straws are produced in threshing ripe alfalfa for seed. They are much higher in fiber and lower in protein than the alfalfa hays which are given for comparison. Alfalfa hay No. 1 was grown in Salt River Valley; alfalfa hay No. 2 was grown at Yuma.

Sorghum refuse was the residue after the cane had been crushed for syrup.

Cotton stalks hurds were produced by crushing the stalks to remove fiber for commercial purposes. The rather high protein is due to the removal of the fiber and to the seed that remained in unopened bolls.

MISCELLANEOUS ANALYSES

On two occasions, when large numbers of livestock have died without apparent cause, the chemists have examined material for poisonous substances. A number of hogs, near Yuma, died in a field of Sudan grass, giving cause to suspicion poisoning by hydrocyanic (prussic) acid, as is known to happen sometimes with drought-stricken sorghums. The animal materials were badly decomposed when received, but samples of the grass were sent to the laboratory with the roots balled in damp soil when taken up. No trace of hydrocyanic acid could be discovered in this grass. Evidence seemed to indicate that the hogs had died of heat and that the Sudan grass was not at fault.

In a second case a large number of sheep had died on the range in northern Arizona. Careful examination of the stomach contents by the Station botanist, Professor J. J. Thornber, failed to reveal remains of lupines or other poisonous plants, although saltbush leaves and other vegetation could be identified. Chemical analysis showed the absence of hydrocyanide acid, arsenic and heavy metals, and strychnine.

Several poultry and stock tonics that were being sold to

farmers and stockmen have been brought in for examination by the Extension Service. One of the most interesting of these was a remedy for sheep reputed to be efficacious in curing even such ailments as scab. It was composed of salt, sulphur, carbon and tobacco.

DATE PASTEURIZING AND RIPENING APPARATUS

For several years we have pasteurized the entire output of the Tempe Date Orchard with a small pasteurizer heated by a gasoline brooder heater. The apparatus was constructed originally for experimental purposes that made possible the marketing of soft dates under adverse weather conditions. It was too small, however, to handle the large crop of the orchard on a commercial basis, so in 1916 a new and larger pasteurizer was decided on. The process being new and no experimental data existing as to the selection of material for such appliances cement was selected. An eight-chamber pasteurizer, each chamber having a capacity of about 30 pounds of fruit, was constructed. The walls were approximately four inches in thickness with an inch and a half core of "button lath" made of paper and plaster of paris for heat insulation. It was found impossible to bring the temperature much above 55 deg. C. with boiling water and all the radiating surface that could be arranged in the chambers. Cement proved not only difficult to heat, but the side walls and top of the chamber condensed moisture to such an extent that one of the main purposes of the process, namely, to reduce the moisture content of the fruit, was defeated. Later steam coils were placed in a few of the chambers and the apparatus was found well adapted for ripening by heat, which requires a rather high humidity to prevent the fruit from shriveling. Cement can be molded into convenient form for date pasteurizers, but in our experience it has proved much inferior to wood with metal lining.

The past summer we have constructed a new pasteurizer of wood, which has proved entirely satisfactory. The sides and top are of tongue and groove flooring, double thickness with two-ply of building paper between. It is lined throughout with thin galvanized iron, and drip pans are placed at the bottom of each chamber to catch any honey that runs from the dates. There are five chambers, each taking eleven of our standard trays, 20x30 inches and 2 inches deep, holding conveniently 10 or 15 pounds of dates.

This capacity is sufficient to handle the entire day's picking in one or two heats. The bottom coil of steam pipe has eight laps with three trays above it; the other coils have six laps with two trays between each coil. With 10 to 15 pounds steam pressure, 2½ to 4 hours is sufficient to pasteurize the dates well, the time and pressure depending on the size of the dates and their moisture content. Very moist dates require open ventilators to carry off the excessive moisture, and consequently higher steam pressure to maintain the chamber at pasteurizing temperature, 65 to 70 deg. C. The pasteurizer serves very well as a drier for culls, and dates that were too sour for use when dried at ordinary temperature, made fairly good dry packing dates when dried rapidly in the pasteurizer.

The heating system is closed and the boiler placed in a pit below the level of the pasteurizer for drainage. The supply and return pipes are separate, each coil being connected independently so that as many coils as desired may be turned on. The steam is supplied by a three-horse-power dairyman's boiler fitted with an oil burner, using distillate. With the closed system only a few quarts of water need be pumped into the boiler at the beginning of operations each day to replace what is lost through the air valves. After the burner has been adjusted to maintain the desired pressure the apparatus requires little more attention than the steam heating system in a residence. The boiler is about as small as can be used conveniently, but by adjusting the burner properly the desired pressure may be held quite economically; and one is relieved of the fear that the water will get too low. This size boiler would easily supply twice the present pasteurizer capacity, and with constant supervision would do much more.

A carbon dioxide ripener of greater capacity than the one in use heretofore has also been added to the equipment. This was made by cutting a large opening in the head of a new galvanized iron oil barrel so as to leave a flange of 1½ inches and bolting and soldering the iron ring from the head of a No. 3 Acme churn to this flange. About six feet of heavy rubber garden hose with convenient couplings and fittings serve to connect the three-quarter inch opening in the bottom of the oil barrel with the gas cylinder. The barrel may be mounted on trunnions to facilitate removing the dates after the carbon dioxide treatment.

V. E. VINSON,
Biochemist.
C. N. CATLIN,
Assistant Chemist.

IRRIGATION INVESTIGATIONS

THE LOWER SANTA CRUZ VALLEY

The investigations started previously in the Casa Grande Valley have been continued during the past year. The surface waters have been measured at Tucson and Sasco, and in part at points farther west, but the measurements of seepage losses have not confirmed those of the previous year as could have been expected. Water table fluctuations, including the special observations in the vicinity of active pumping plants, have been confirmatory of those previously reported.

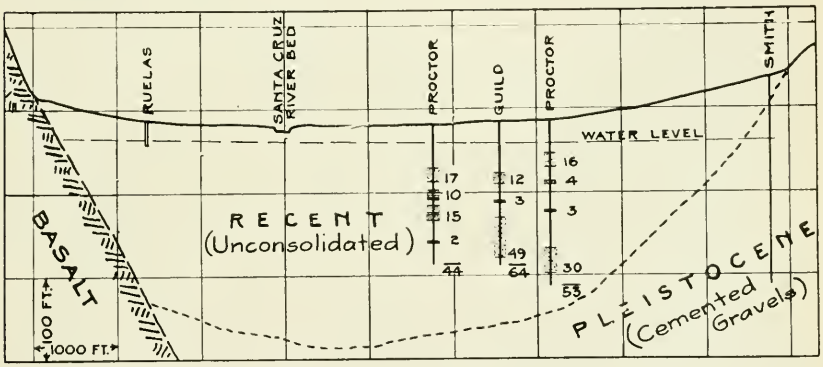


Fig. 12.—Section across Santa Cruz Valley at the point of the Tucson Mountains, seventeen miles northwest of Tucson

The drilling of an almost dry well at Rillito has led to special study of that locality. The well, that of Dr. Mark B. Smith, is just on the edge of the Recent valley fill and consequently it was drilled wholly in Pleistocene deposits. These deposits, like those of the Rillito Valley,* have been so altered by cementation and by decomposition of feldspathic grains that they are quite impervious. The important economic effect of this change is that the area of good water-bearing strata from Rillito southward is confined to the immediate river valley, and only rarely can it be expected that good wells will be found outside of this area. The nearby wells of Guild Bros. and Henry Proctor are among the best in Arizona. A cross-section of this part of the valley is shown in Fig. 12, and the logs

*Ariz. Agr. Exp. Sta. Bul. No. 64, pp. 156-160.

of the four wells are projected on the section. Downstream from this locality a short distance is the Rillito groundwater-fall, where the water table sinks abruptly from the shallow depth of 18 feet to a depth of 120 feet, in a distance of less than one mile.

Settlement in the Lower Santa Cruz, or Casa Grande, Valley, has proceeded rapidly, and much groundwater development has taken place. It is to be hoped that the Gila River floodwaters will soon be stored and made available, for the groundwater supply alone cannot be expected to water the entire area of land already patented or entered upon.

THE LOWER GILA VALLEY

Mention was made in the last annual report of the discovery of good water-bearing gravels in the Antelope Valley, which is the section of the Gila Valley from Mohawk to Dome. The good gravels underlie a thick bed of silt and fine sand, in which many costly attempts to develop irrigation supplies have proven failures. The logical inference of the deeper drilling was that the Recent valley fill was similarly constituted throughout the whole extent of the Lower Gila Valley. This hypothesis has been confirmed by recent drilling in the valley east of Yuma, though in this location the overlying beds of silt are found to be considerably thicker than near Wellton.

The aggregate potential groundwater supply thus revealed is very extensive and will permit of important development. It is likely, however, that the good gravel stratum is confined to the bottomlands and is not continuous beneath the mesa lands to the north and to the south of the valley.

Two precautions should be pointed out at the beginning of development of these groundwaters. First, the Gila Valley, in both soil and water, contains much alkali. The amount present is variable, and in some places is beyond the limit of toleration of ordinary plants. Consequently, the first well drilled in a new locality should be considered a test well, and an analysis of the water should be obtained before further expenditures are made. In some places where surface water in the river may be had by means of canals or by pumping for a considerable part of the year, groundwater with 75, possibly with as high as 100, parts of salt per 100,000 may be used during the months when the river is dry.

The other precaution was referred to in the last report. A defi-

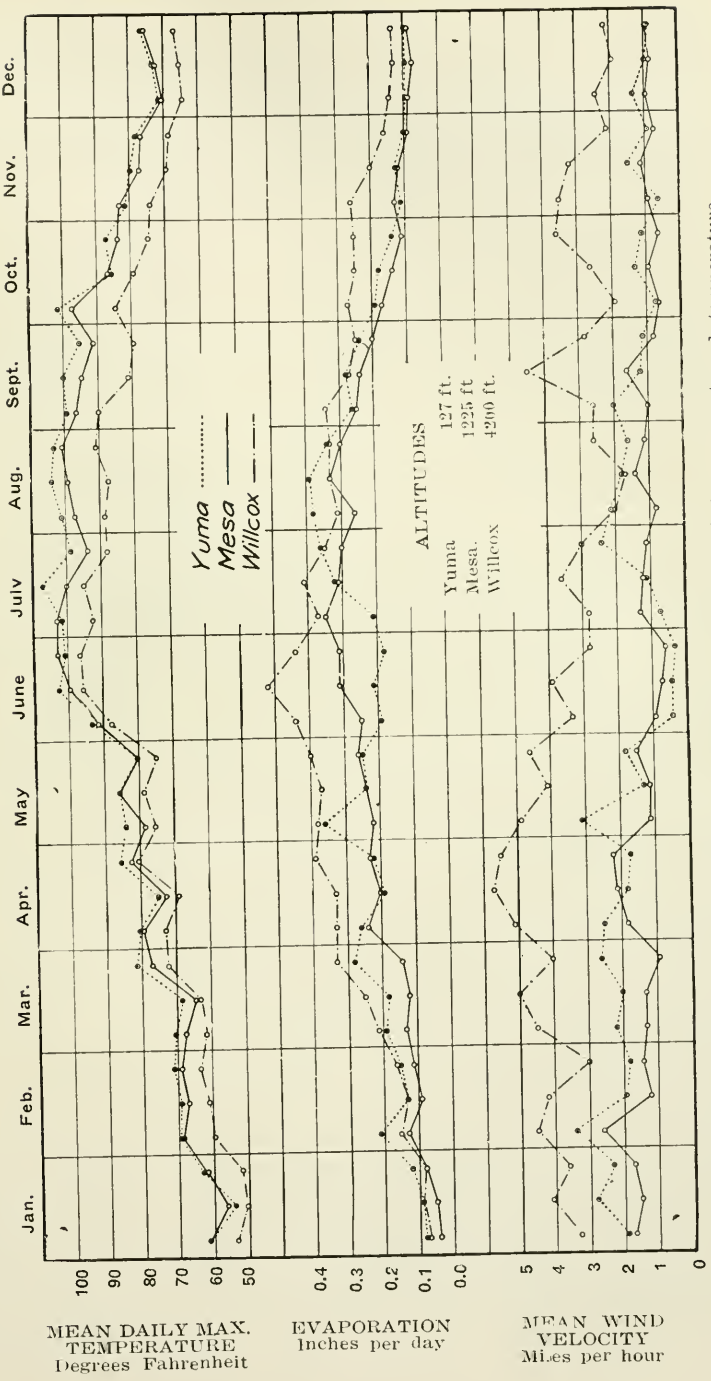


Fig. 13.—Diagram showing correlation of evaporation, with wind movement and temperature.

nite policy of building farmsteads on the margins of the bottom-land should be adopted and all newcomers should be warned against building residences on ground subject to injury by river floods. It is possible that better river control by reservoirs on the Gila and its tributaries will reduce the menace in the future and levee protection will be possible to a limited extent.

WELL DRILLING AND DEVELOPMENT

Considerable time has been spent during the past year accumulating data on the drilling and perforating of wells and more particularly on the development of the wells after perforating. This has been done with a view to early publication.

EVAPORATION AND DUTY OF WATER

For several years this department has desired to undertake special investigations to study the relationship between the evaporation-rate and the duty of water. Although evaporation records are common and have been kept at various times in many places, yet the mass of data thus accumulated is almost worthless for comparative purposes, because of the absence of standardization in equipment and method, and because as a rule no contemporary observations have been made of other climatic factors. Clearly, it was the province of the United States Weather Bureau to control such standardization, and in 1915, as soon as the Bureau had made tentative plans for a standard evaporation pan, this office had several of them built. Later, when Congress made appropriation for twenty-five Class A evaporation stations, three of them were obtained for Arizona under cooperative arrangement. This station selected the sites and furnished the pans and standard enclosures. The Weather Bureau furnished hook gages, rain gages, and maximum and minimum thermometers. The observers are paid by this station.

The purpose being to test the hypothesis that water requirements of plants are proportional to the evaporation-rates, three locations were chosen widely separated in climatic conditions. They are Yuma, the Salt River Valley, and near Willcox. The altitudes above sea level are 127 feet, 1225 feet, and 4200 feet, respectively. Approximately similar soil conditions were found in the three places, and in each place the evaporation pan and other instruments

were installed in the center of an alfalfa field. The duty of water for alfalfa is to be obtained.

Fuller descriptions will be given in a separate publication, but the general results of the first year's observations are given herein in Fig. 13. The temperature, the wind movement in miles per hour, and the evaporation in inches of water, in ten-day periods, are shown by graphs.

A close agreement between the temperature and the evaporation graphs is very apparent for all three locations, but a careful examination reveals that the agreement is modified by the wind movement. Thus, the decreasing wind movement near Willcox in May and June prevented so rapid an increase of evaporation as in March and April. The apparently erratic curve for Yuma in the summer months is due to the raising of a seed crop. At Yuma and at Willcox, in August, the wind movement was nearly equal and the difference in evaporation-rate appears to be due to difference in temperature.

Reduced to lowest terms, the evaporation-rate depends upon temperature and the vapor pressure directly at the water surface. The first of these two factors is expressed here by the daily maximum temperature instead of by the daily mean temperature, which is commonly used. The second factor depends upon the relative humidity in the vicinity, and the air pressure, in addition to the wind movement. Air pressure varies mainly with altitude, and the extent and direction of this variation has been much debated. The high evaporation-rate near Willcox is attributable in the main to the rapid wind movement, but may be due in part to the fact that the evaporation station near Willcox is in an isolated alfalfa field surrounded by semi-desert conditions, while at Yuma and Mesa the alfalfa fields are but parts of great irrigated valleys. Willcox lies on the western edge of a region which some investigators have asserted to have the highest evaporation-rate for the United States.

The importance of these investigations to agriculture is appreciated when one recalls that the loss of water by transpiration from a well-developed field of alfalfa is greater than the evaporation loss from an open water surface. The average annual loss from a well-irrigated alfalfa field cannot differ very greatly from that of a standard evaporation pan placed within the field. Farmers in the Sulphur Spring Valley have added incentive to plant windbreaks, to cultivate after irrigating, and to raise crops having low water requirements.

MACHINE-MADE CEMENT PIPE

On account of the great importance of water economy in Arizona this Station has taken a lively interest in the manufacture of cement pipe and its use for irrigation pipe lines. In 1907 the Station published a bulletin on the subject and has constantly advocated the use of cement pipe for irrigating streams of moderate size requiring pipe up to 24 or possibly 30 inches in diameter. For farms that are under pump irrigation, pipe sizes from 8 to 20 inches in diameter are required commonly.

During the last few years pipe machines have been developed for making cement drain tile in the Middle West, and during the past year these machines have been modified so as to make irrigation pipe. The opportunity presented itself to this department to bring one of these machines to Pima County and to study machine-made pipe and pipe-making. The results of these studies have been prepared as a bulletin and will be published in the near future.

The general conclusions of the study are that pipe-making by machinery is entirely practical, that the pipe is much superior in quality to hand-made cement pipe and that the cost is less. The field for a new industry is open and inviting and pipe factories should be built and equipped at a half dozen places in central and southern Arizona. The ultimate result will be greater water economy, and an extension of the irrigated area.

For the larger laterals and main canals cement lining is the best method of improvement. Careful estimates show that by lining the canals of the Salt River Valley enough water will be saved to permit an increase of 25 percent in the project area.

EXPERIMENT STATION PUMPING PLANTS

During the expansion of the Experiment Station work it has been necessary to develop many pumping plants, both for outlying stations and for the campus and the University Farm. A summary of these plants with general comparative data is of interest and is shown in Table XXI.

In a semi-arid region such as Arizona water supplies are of primary importance. The Yuma and Prescott plants are for domestic supply only, but the others are designed for both domestic supply and irrigation. The conditions are very variable, however, and the fact that the design of pumping plants requires specialized training is well illustrated by the list. It is to be noted that no two

TABLE XXI.—EXPERIMENT STATION PUMPING PLANTS

Location	WELL				PUMP		ENGINE	
	Type	Total Depth	Water table	Draw-down	Type	Discharge	Type	Rated power
		Ft.	Ft.	Ft.		Gal per min.		H.P.
Farm at Tucson....	Caisson with two feeders	90	15	10	Hor. centr.	720	Oil engine	15
Farm at Mesa.....	Caisson	40	25	4	Hor. rotary	62	" "	5
Yuma Date Orchard	Driven	90	12		Vert. plunger	25	" "	2½
Prescott Dry Farm	Drilled	318	265		Vert. plunger	11	Gasoline engine	6
Cochise Dry Farm..	Bored	130	75		Double-acting plunger	100	Oil engine	6
Irrigation laboratory	Dug and drilled	281	81					
Temporary, for testing well.....				10.6	Vert. turbine	705	Motor, belted	35
Permanent, for campus supply..					Hor. centr.	400	Motor, direct-connected	20

wells are of the same type, yet each is best adapted to the local conditions.

The Mesa and Yuma plants are new. For the Mesa plant a rotary pump was selected, because of the shallow water table, the moderate yield and the necessity for pumping extensively on two different lifts. The pump is set just above the water level and is self-priming. The engine is depressed in a pit, which will become the basement of a small building later on. This arrangement obviates the necessity for a long belt. For the Yuma plant a reciprocating pump was chosen on account of the small discharge. The driven well being too small to admit a pump cylinder, a pit was dug to the water table, the well pipe was cut off and threaded, and the cylinder was attached directly to the pipe. This scheme assures the greatest possible draw-down and, therefore, yield.

The engines are nearly all oil engines (that is, they burn tops, a low-grade distillate), with the exception of the irrigation labora-

tory, for which electric current from the central power plant of the University is available. The engines are all of the four-cycle type, and it may be added that the Experiment Station strongly recommends that type in preference to two-cycle hot-ball engines*.

This department has designed also a new water supply system for the University campus during the past year. The new system is unique and its main features should go on record at this time. The pump room is situated in a basement 74 feet by 24 feet. At one end is a reinforced concrete sump of 48,000 gallons capacity, into which the discharge from the well is delivered. The pressure pumps are in duplicate, of 100 gallons per minute capacity, and start automatically when the water pressure drops to 26 and 23 pounds per square inch. When the pressure reaches 33 pounds, the pumps stop automatically. The discharge line is connected with a 5,000-gallon pneumatic pressure tank which is kept about two-thirds full of compressed air. Floor space is reserved for another pressure tank to be added later, and the remaining space is for fire service pumps. The new system is giving good service, with better pressure than was had formerly with the elevated tank.

EXTENSION WORK

For two months during the height of the pumping season in 1917, this department kept one of its assistants in the field assisting farmers with refractory engines and pumps, and helping them to secure better fuel economy. The Casa Grande Valley and the McAllister and Whitewater districts were covered in this way.

The irrigation engineer devoted two weeks in June, 1917, to lecturing in Navajo and Apache counties. Ten lectures were delivered. During this trip and throughout the year assistance has been given to farmers and canal companies on irrigation and other farm engineering subjects.

GRADING LAND FOR IRRIGATION

Considerable study has been given to the subject of preparing land for irrigation, particularly land on relatively heavy slopes as from 25 to 100 feet per mile. The principal agricultural valley lands in Arizona lie at slopes of 8 to 15 feet per mile, and these lands can be irrigated very efficiently. On lands that take water

* Vide Bul. 74, Ariz. Agr. Exp. Sta., pp. 429-433.

readily the water can be run parallel to the steeper side of the field, while on the heavy clay soils the flatter grades are used.

With the extension of agriculture to lands farther from the rivers, steeper slopes are encountered, and during the past year much new land with slopes of over 25 feet per mile has been developed. The question has arisen as to the desirable slope in which to lay out the borders or rows. In one locality 8 feet per mile has been adopted arbitrarily, although it has entailed much greater expense for grading than would a steeper grade for the direction of irrigation. Moreover, the flatter grade introduces a heavy side-fall, or cross-slope, which may become very troublesome during irrigation.

The question involves the possibility of irrigating in furrows or lands with steep gradient. Can the field be wetted uniformly? The efficiency of irrigation depends upon the uniformity of distribution even more than upon the average depth applied. If a large unit head of water is turned into each land or furrow, the soil may be washed or eroded, or, on clayey soil, the water may reach the lower end and be turned off before much has been absorbed. If the head is too small, then on sandy soil it will be absorbed in the upper part of the field and the lower part of the field will receive a relatively light irrigation. But the head can be varied between quite wide limits, and it should be the dependent variable. On each field it is necessary to ascertain by trial the optimum quantity for the unit head.

The length of the furrow, likewise, can be varied if taken in time. One rancher in the Salt River Valley during the past summer ran water in furrows 330 feet long and his neighbor ran the same stream, when it came his turn in the rotation, in furrows one-half mile long. Many cases have been noted where water has been wasted downward by deep percolation below the reach of plant roots in the upper part of fields, and the cause assigned has been that the lands were too long. But in most cases the waste of water could be prevented by turning the direction of irrigation so as to get more slope or, the more practical way, by increasing the unit head of water. On the other hand, sometimes the rancher finds that the lower part of his field is getting the larger proportion of the water. Usually he wishes to regrade his field so as to have less fall in the lands, but his more rational solution is to reduce the unit head.

The character of the soil, the crop, the slope, the length of run

and the unit head are interdependent upon each other. Any one may be taken as a function of the others, and the efficiency of irrigation is a compound function of them all. In many cases of laying out new projects, the head of water has been assumed as one of the independent variables, and the slope for the furrows has been made to conform thereto, but probably the better way would be to run the water down the natural slope and thus save in the cost of grading and obviate the troubles accompanying a heavy cross-slope, and then regulate the length of furrows and the unit head to obtain a uniform distribution of the water.

The importance of problems in the application of water is indicated by the fact that great diversity of practice exists through the State. The Yuma and Salt River valleys use the border method largely, the Upper Gila Valley uses the border method, but often without the borders, the Little Colorado region practices the corrugation system as in the Northwest, while in Yavapai County the Colorado method of flooding from field laterals prevails. In all of these sections the water is run down the natural slope, except in the Yuma Valley, where it has become the custom to grade the lands level. A discussion of land grading for irrigation has been contributed to the technical press.*

WATER RESOURCES

At the time of the entrance of the United States into the world war, a survey was made of the condition of irrigation water supplies in Arizona**. On the whole conditions were found to be favorable. Two years of exceptionally heavy rainfall had filled the Roosevelt reservoir and had caused increased flows in all the streams of the State. It was obvious that the limiting factor in the increase of agricultural production in this State would not be the water supply, but rather the amount of labor available. Indeed, it was possible the past summer to grant temporary water to 15,000 additional acres in the Salt River Valley.

Since the time of that survey, the abnormally low rainfall in the important watersheds of eastern Arizona has made our water supplies a matter of grave concern. Already the Upper Gila Valley and northeastern Arizona have felt the water shortage and the Roosevelt stored supply has been reduced 35 per cent. Attention is again called to the need of storage on the Gila River. To the great

*Western Engineering IX, 1, Jan., 1918.
**Arizona Magazine VII, 7, May, 1917.

misfortune of Arizona, there has been enough water wasted through the San Carlos reservoir site during the past three years to have filled the proposed reservoir five times. The most feasible reservoir site on the Gila River is at San Carlos, and the efforts of the entire State should be concentrated on obtaining that reservoir at the earliest possible moment.

Groundwater supplies also are dependent upon the rainfall, but the effect of seasons of high and low rainfall is not so quickly felt as in the case of surface supplies.

THE PROPOSED STATE WATER CODE

Special effort has been made, whenever possible, during the year to present the merits and the urgency of the modern water code, with its ideal system for adjudicating existing water rights without litigation, for initiating new rights, and for State control and distribution of water supplies. A paper outlining the proposed code and relating the success of the modern system in the other irrigated states of the West has been published as Extension Circular No. 11. Five meetings have been addressed on the subject, and resolutions were adopted by the Second Arizona Irrigation Conference and the National Irrigation Congress urging Arizona to fall in line with the other states.

G. E. P. SMITH,
Irrigation Engineer.
A. L. ENGER,
Assistant Engineer.

AGRICULTURAL EDUCATION

The University of Arizona College of Agriculture is especially concerned at this time in meeting the emergency educational requirements that it may be made to serve. The opportunities that now await the trained agriculturist particularly relate (1) to active farming operations in which any one with a fair degree of skill and business ability has now unusually good chances to prosper. Such staples as alfalfa, with dependent livestock industries; cotton, and others of the fifty commercial crops that may be grown in this region, offer varied opportunities for the exercise of skill and advanced knowledge on the part of the investing proprietor. Land values are yet comparatively moderate in this region and young men with agricultural training and some practical experience on the farm are recommended to take up farming as a permanent occupation. (2) Many opportunities in agricultural industries, those directly connected with farming operations, afford a second class of opportunities for which scientific agricultural training is indispensable. Creameries, canned-milk factories, dairies, alfalfa meal mills, canneries, small packing houses, pickling establishments, cotton gins, oil presses, fruit-drying establishments, pedigreed seeds, pure bred livestock, and fancy specialties of all kinds are instances of the industries that, properly conducted, may become foundations for profitable businesses. (3) Professional agriculture affords still another class of opportunities to the agricultural college graduate. At this time there is an unusually strong demand at excellent salaries for trained men to serve in technical Government positions, as county agents in the Extension Service, as reclamation and forest service employes, and as teachers of agriculture in schools and colleges.

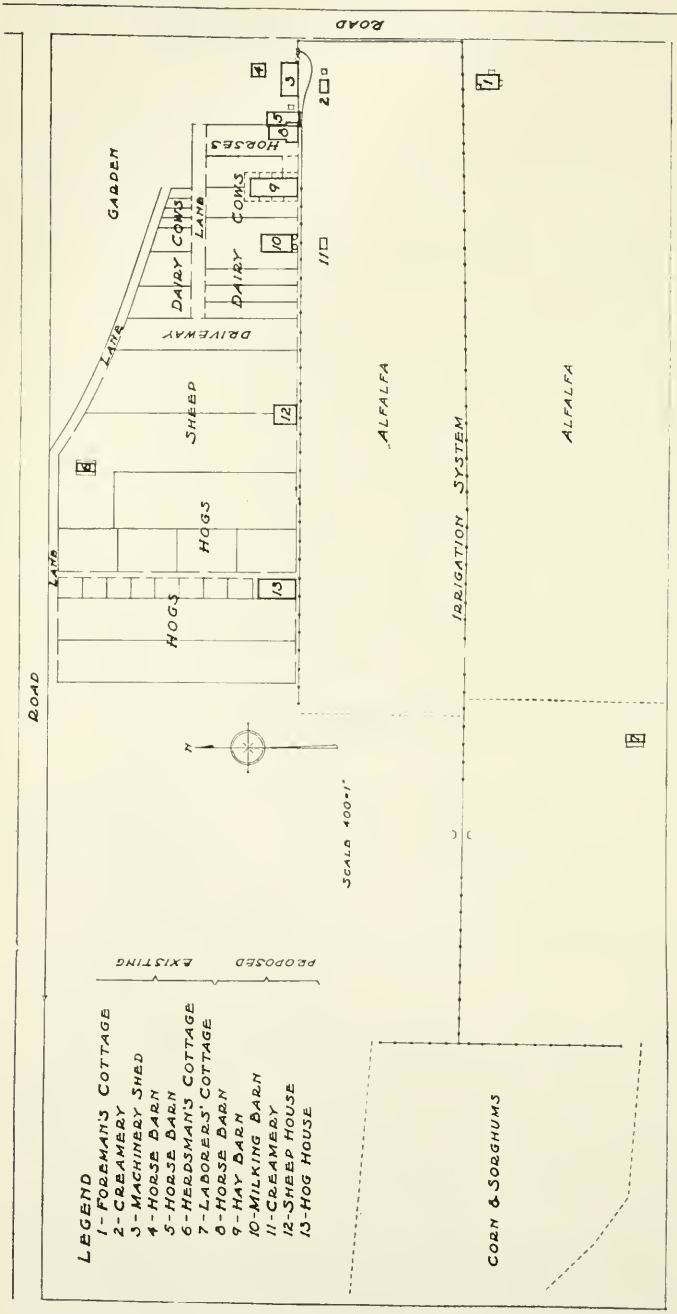
In the wide field of Southwestern agriculture we therefore have opportunities suited to every temperament, to different degrees of training, and to varying personal situations; and particular effort is being made at this time to bring those young men and women not otherwise called upon for service in time of war to enter some one of the several educational courses in agriculture offered for their consideration.

The College of Agriculture has attempted to so arrange the curriculum that students who have taken a large part of their instruc-

tion in other colleges may complete their agricultural education at the University of Arizona without loss of time or credits in making the change, and thus avail themselves of the opportunity to obtain a working knowledge of the various types of farming practiced under semi-arid conditions. For this reason, and also because of the strong migration of new families into the Southwest, the larger part of our agricultural student body enters with advanced credits, some coming each year for their senior year's work. This condition has been met by group requirements with a minimum of specific requirements in the four years' course rather than a rigid sequence of subjects which would be practicable only for those entering as freshmen. Consistent with the requirements of four-year courses in other Agricultural Colleges, about one-half of the total units necessary for graduation are in the pure sciences on which agriculture rests, in English and other modern languages, mathematics, drawing, economics, and military tactics. A smaller number of units, totaling 25, is required in a few specific agricultural subjects which are considered essential in the successful pursuit of any line of agricultural work. To insure that the student specializes sufficiently to take a position in some particular field, a major of 16 additional units in one of seven groups is required. The groups are agronomy, horticulture, animal husbandry, agricultural chemistry, biology, rural engineering, and economics. An additional 14 units chosen from the major group or from other agricultural subjects are required to round out the student's purely agricultural training. The balance of the 124 required units, amounting to six units, are free electives. This elastic requirement permits the arrangement within its limits of courses to meet the needs of the individual who wishes to prepare for professional work, or to engage in farming, or who comes from other colleges with his course nearing completion.

A special four years' vocational teacher's course in Agriculture is also offered for those who wish to qualify for service under the Smith-Hughes Act. The essential difference between the vocational teacher's course and the regular course is the substitution of sufficient work in psychology and education to meet the State requirements for a first-class teacher's certificate, and of certain desirable courses in agricultural education.

The four-year courses are open to high school graduates and to persons 21 years of age who have not completed the usual entrance requirements, such persons being permitted later to substitute college credits for deficiencies in preparation. To meet the urgent



UNIVERSITY OF ARIZONA
TUCSON - ARIZONA
AGRICULTURAL COLLEGE FARM
S½ SE.¼ SEC. 19, T. 13 S., R. 14 E. - G. & S. R. B. & M.

Fig. 14.—Elevation 2332 feet.

need of a group of persons under 21 years of age, who are also deficient in preparation necessary to carry much of the work of the four years' course a two years' course is available. The work of the short course is selected to be as practical as possible, but the student is held to the same standard of work regarding time and scholarship as is required in the four-year courses. Credits obtained by short-course students are applicable to the regular course.

Beginning January 21, 1918, the College of Agriculture will offer a special short course of four weeks adapted to the needs of persons who cannot take a full semester's work. There will be no entrance requirement for this course. The course will be so arranged that a wider range of purely agricultural subjects may be taken simultaneously than is possible in regular University classes. No University credit can be given for these courses, but certain subjects started in the four weeks' short course may be continued in the Correspondence School and given credit.

EQUIPMENT

The educational equipment has been maintained and improved, recognizing the fact that equipment should not be allowed to run down against the time when normal conditions return. The new Agriculture Building has received furnishings, apparatus and supplies during the year, materially improving facilites for both experimentation and instruction. The gardens and outside physical properties have likewise been maintained in proper form.

University of Arizona Agricultural College Farm

The University of Arizona Agricultural College farm, consisting of 80 acres of bottomland three and ont-half miles from the campus, is being further reclaimed and affords illustrations relating to the leveling of land; the reclamation of black alkali by means of gypsum, barnyard manure and other treatments; the growing of various forage crops; the manufacture of silage; the pumping and economical distribution of water; and the maintenance of various types of livestock, including work stock, dairy cows, beef cattle, hogs, sheep and poultry.

Resulting from the necessity of maintaining a considerable equipment of livestock upon the farm for the use of classes in animal husbandry, the affairs of the College of Agriculture farm are now conducted with a view to the maintenance of a considerable

animal population thereupon. We have upon the place at this time five horses and mules, twenty-nine dairy animals, eight beef cattle, thirty-seven sheep, eighteen hogs, and eight ostriches; all of them illustrating various types of animals and affording good opportunity for the study of livestock by student classes.

A second silo has been constructed at the University Farm this year, adjoining the first and so situated that it may be included within the gable of the new milking barn which is contemplated at this point.

A development plan has also been laid out for the farm, including particularly buildings and pens for the accommodation of the livestock. Additional land should be leveled as soon as finances permit and additional areas made productive in order to accommodate as far as possible the increasing amount of livestock on the farm.

Educationally considered, the leading features of the farm as it is developed, relate to the reclamation of rough alkali ground; to the development, pumping and distribution of groundwater supplies; to the production of standard forage crops; to the study of various plant introductions and ornamentals; and to the study of various types of livestock.

ATTENDANCE

Attendance upon the College of Agriculture for the year, as expected under war conditions, has fallen away seriously in spite of a somewhat extensive campaign the previous spring with circular information for the purpose of maintaining the student personnel. In this respect our experience has been similar to that of Colleges of Agriculture throughout the United States. In no single instance, so far as the writers have been able to ascertain, has such attendance been equal to that of last year. Colleges located in certain sections of the country, however, seem to have suffered more than others. Generally speaking, the Rocky Mountain region has suffered most. The Middle Western colleges have suffered less (with the exception of Wisconsin—about half the attendance last year); and apparently the Pacific Coast institutions have suffered least of all, up to this time.

In such an exigency, plainly the maintenance of attendance must be accomplished by drawing upon those classes which are not directly called upon in connection with the war. Courses that

women can take, including poultry, horticulture and general farm management, should be emphasized; also short courses for the benefit of that class of young men between common or high school age and 21 years. In many cases bright students, even though not qualified to enter the full four-years' course of study, may derive great benefit from short-course work, ranging in this institution from four weeks to two years.

ANALYSIS OF ATTENDANCE

In the Twenty-seventh Annual Report the attendance for the first semester only of the college year 1916-1917 was given. The complete registration for that year was: Number of students in two and four years' courses and specials 56; other students electing agriculture 2; total 58. For the first semester of 1917-1918 there are enrolled: Students in two and four years' courses and specials 27; other students electing agriculture 4; total 31.

An analyses of the causes thus affecting the student body resulted as follows:

Graduated (3 in military service)	7
Returned	14
Failed or withdrew during semester (several now in military service)	12
Entered military service	12
Changed course	1
Special students completing work	2
Non-resident students left State	2
Permanent agricultural employment	4
Other permanent employment	2
Total	56

As elsewhere throughout the country, the military situation appears as the main cause of losses from the student body. In addition, the same cause in large part accounts for a decrease in the number of new students enrolled.

FINANCIAL

Following is a statement of expenditures made on behalf of educational work during the current year:

R. H. FORBES,
Dean, College of Agriculture.
A. E. VINSON,
Professor of Agricultural Chemistry.

AGRICULTURAL INSTRUCTION EXPENDITURES FOR THE YEAR ENDING JUNE 30, 1917

		Chemistry	Agronomy	Horticulture	Animal Husbandry	Plant Breeding and Botany	Totals	
Morrill Fund (Federal)	Salaries	$ 1419.84	$ 255.46	$ 1283.30	$ 2541.65	$ 340.65	$ 5840.90	$ 5,840.90
Univ. Farm fund sales		.....	.....	54.02	943.25	.....	997.27	
	Feedstuffs	.....	.....	.....	.....	.....	638.07	
	Farm implements	.....	.....	.....	.....	.....	26.35	
	Pumping expense	.....	.....	.....	.....	.....	414.26	
	Freight and express	.....	.....	.....	.....	.....	11.47	
	Auto repairs and supplies	.....	.....	.....	.....	.....	261.72	
	Miscellaneous	.....	.....	.....	.....	.....	1408.25	
	Pipe line	.....	.....	.....	.....	.....	377.00	$ 4,134.39
Univ. Farm fund (State)	Salaries and wages	.....	.....	.....	.....	.....	5232.30	
	Feedstuffs	.....	.....	.....	.....	.....	972.78	
	Farm implements	.....	.....	.....	.....	.....	338.98	
	Auto repair and supplies	.....	.....	.....	.....	.....	419.66	
	Poultry houses	.....	.....	.....	.....	.....	493.77	
	Poultry (birds)	.....	.....	.....	.....	.....	.....	
	Clearing land	.....	.....	.....	.....	.....	1559.06	
	Miscellaneous	.....	.....	.....	.....	.....	709.24	
	Cattle	.....	.....	.....	.....	.....	2178.90	
	Pumping	.....	.....	.....	.....	.....	129.83	
	Hogs	.....	.....	.....	.....	.....	70.00	
	Sheep	.....	.....	.....	.....	.....	173.03	$12,278.85

University of Arizona, College of Agriculture

Agricultural Experiment Station

Bulletin 84

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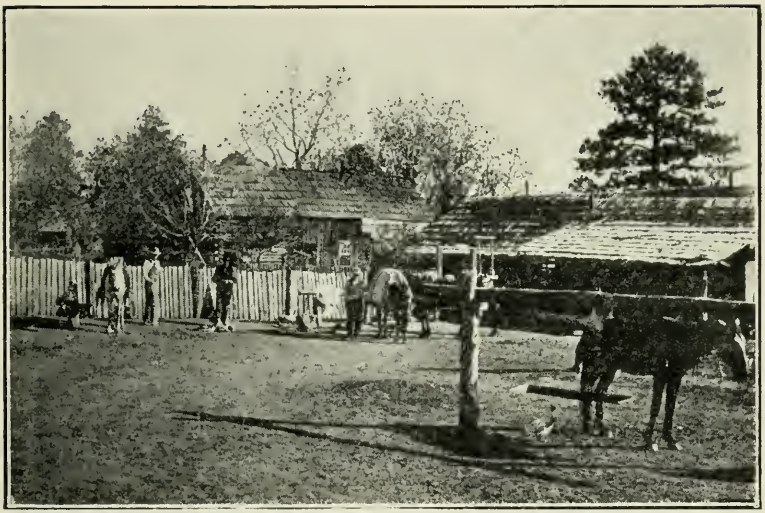

A pioneer home, Gila County, Arizona

Dry-Farming in Arizona

By A. M. McOMIE
ASSISTED BY C. R. FILLERUP AND L. L. BATES

Edited and Revised by
H. C. HEARD

Tucson, Arizona, February 1, 1918

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DeLore Nichols, B.S. ..... County Agent, Coconino County
Hester L. Hunter ..... Secretary Extension Service
Frances M. Wells ..... Secretary Agricultural Experiment Station

The Experiment Station offices and laboratories are located in the University Buildings at Tucson. The new Experiment Station Farm is situated one mile west of Mesa, Arizona. The date palm orchards are three miles south of Tempe (co-operative U. S. D. A.), and one mile southwest of Yuma, Arizona, respectively. The experimental dry-farms are near Cochise and Prescott, Arizona.

Visitors are cordially invited, and correspondence receives careful attention.

The Bulletins, Timely Hints, and Reports of this Station will be sent free to all who apply. Kindly notify us of errors or changes in address, and send in the names of persons who may find our publications useful.

Address, The Experiment Station,
Tucson, Arizona.

PREFACE

Since the rainy season of 1905, when accidental plantings of barley by teamsters feeding their animals by the roadside attracted the attention of land-hungry settlers, a persistent and increasingly ingenious effort has been made to discover methods of utilizing our semi-arid lands for farming purposes. In the southern part of the State at the altitudes of the great valleys it is fairly well determined that the ordinary rainfall should be supplemented by stored or pumped irrigating waters, used at critical times to start or save a crop. Subsequent work in the northern part of the State at somewhat higher average altitudes indicates that it is possible, with good management and skillful handling, to produce a fairly reliable output of dry-farmed forages without the help of irrigating water.

In the southern part of the State the crops apparently best adapted to altitudes of 4000 feet with a long growing season, include Kafir, Club-top sorghum, milo, and tepary beans. In the northern part of the State, under less stringent conditions, the crops that may be grown include not only Kafir, Club-top sorghum, milo, and tepary beans, but also various Indian corns such as Papago sweet corn, White Hopi corn and other quick growing, drought resistant varieties. Sudan grass for hay, potatoes and several varieties of beans, and even orchard fruits, have been found feasible under these conditions.

But of equal importance with the production of these forages has been their preservation as silage, in which form but a small percentage of nutritive value is lost as compared with the very great loss in nutritive value incidental to the common practice of cutting and shocking such forages. It has been found possible at the Prescott Dry-farm to produce from 3 to over 20 tons of silage per acre grown on an average rainfall of 13.4 inches for the past six years. This silage is used to great advantage in connection with live stock of all kinds, particularly range cattle which are subject from year to year to a period of shortage during which an average of two per cent or more die, the remainder coming through in very poor condition for the next season's operations. Experiments with silage at the Prescott Dry-farm last year, which are being repeated on a

larger scale this year, indicate the profitableness of this application of the results of dry-farming operations. A most desirable cooperation therefore may be established between the dry-farmer on the one hand and the range stockman on the other. *The silo in fact, properly developed, is the range stockman's salvation if he will but utilize it to the best advantage.* Silos should be recognized as necessary insurance for the range stockman's business.

This publication is a digest of the results of several years of dry-farming experiments in different parts of the State and relates to methods of culture, crops to grow, feeding of live stock, preservation of crops as silage, and cooperative management between dry-farming and range stock interests. Along these lines of development we believe that large areas of semi-arid lands within the State may be developed to advantage in cooperation with range industries.

R. H. Forbes,
Director.

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Reid's Yellow Dent corn on bottom land at Prescott Dry-farm.

Dry-Farming in Arizona

By A. M. McOmie
Assisted by C. R. FILLERUP and L. L. BATES
Edited and Revised by H. C. HEARD

GEOLOGY AND SOILS

Arizona is divided into two main physiographic provinces, the Colorado Plateaus and the Arizona Highlands; but some physiographers recognize a third, including the southwestern part of the State that lies within the Colorado Desert. Because of the very limited rainfall in this last division it cannot be considered a region with dry-farming possibilities; consequently, only the first two provinces are discussed in this bulletin.

THE COLORADO PLATEAUS PROVINCE

The Colorado Plateaus Province includes northeastern Arizona, southeastern Utah, southwestern Colorado, and northwestern New Mexico. In Arizona its southwestern border runs fairly straight from the northwest corner of the State to a point slightly south of the middle of the eastern boundary. The Colorado Plateaus Province consists, mainly, of a series of table lands 5000 or more feet above sea level with occasional intrusions and extrusions of igneous rocks, particularly in the southeast portion.

In the geologic history of the region three erosion cycles are evident. The first, a monoclinal folding and faulting, gave a pronounced relief to the region. This deformation formed a series of plateaus, descending from west to east, which were subsequently eroded to a peneplain. The second period of faulting left features which are still prominent and reversed the general slope, causing the descent of the series of plateaus from east to west. In the subsequent erosion there was no great vertical reduction of surface, the chief result being the denudation and horizontal stripping back of surface strata. In this period a widespread system of shallow but mature valleys was formed. In the third erosion cycle deep canyons and gorges were formed, the most interesting example being

the Grand Canyon of the Colorado. The peculiar erosion at this time was probably due to both a gradual uplift in the vicinity of the present canyons and downfaulting of neighboring regions. Three distinct periods of volcanic activity are evident, the last being in some cases very recent.

SOILS

Many strata outcrop in belts on the surface of the plateaus, sandstones and shaly sandstones covering the largest area. Soils resulting from the weathering of these strata as a rule are rich in iron, poor in clay, and infertile. In some places sandstone strata are covered with a thin veneer of limestone, and the resulting soil is somewhat more productive. Strata of lava cover the next largest area. Soil formed by decomposition of this material is usually high in fertility, but in the Colorado Plateaus region most of the lava has appeared too recently to allow of much more than mechanical disintegration. Limestone strata outcrop on quite extensive areas, the principal one being the Kaibab Plateau, most of which lies north of the Grand Canyon. Well weathered limestone soils are very fertile. A considerable area of alluvial soils is found. The abrupt slope of the Colorado Plateaus Province, averaging about 200 feet per mile, assists rapid erosion by the young rivers of the region. The finer and more disintegrated portions of exposed strata are transported great distances, separated by gravity, and deposited in the broader valley bottoms. Soils thus formed, composed of the finest materials of various strata, are very fertile. No general statements apply to mountainous parts of the district since they are regions of complex and profound faulting.

WATER SUPPLY

The general arrangement of strata in the plateaus is unfavorable for economic development of groundwater. In places wells have been drilled to a depth of more than 1500 feet without success. However, water is occasionally found near the surface of the plateaus, but only in localized spots, and in many cases it is so charged with minerals that it is unfit for domestic use. Water may usually be developed at a slight depth along the main courses of the valleys, but it is often strongly alkaline. In some places, notably near St. Joseph, artesian water has been found at depths of 200 to 800 feet.

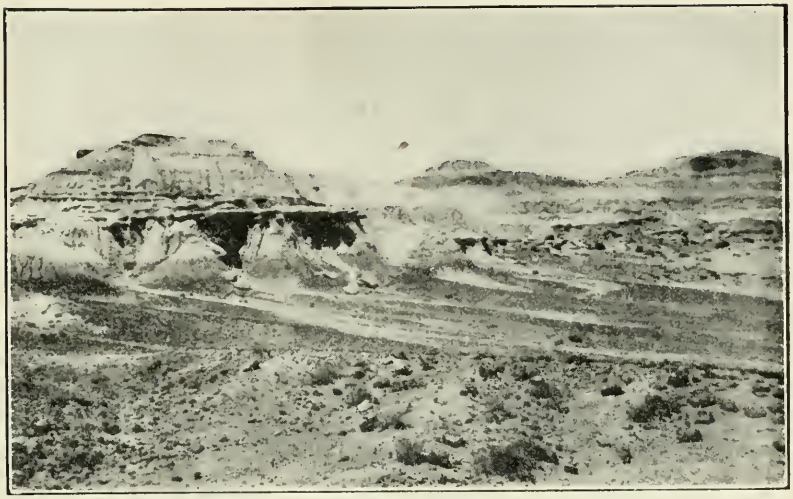

Fig. 2.—Scene in the Petrified Forest, Northern Arizona.

Fig. 3.—Scene in the Petrified Forest, Northern Arizona.

About an inch of precipitation is the normal increase for every 500 feet of added altitude on the border of the plateaus, and for every 250 feet within the border of the plateaus. However, the abruptness of the southwestern and western boundaries of the region causes precipitation of moisture from passing winds to such an extent that the lower elevations in plateaus beyond are arid or semi-arid. In general, only the highest plateaus have an annual precipitation of more than twenty-two to twenty-four inches. There are distinct summer and winter precipitation maxima and great differences between temperatures at the various elevations.

ARIZONA HIGHLANDS REGION

The Arizona Highlands Region, a continuation of the Great Basin, is a mountainous belt from 70 to 150 miles wide, crossing the State from northwest to southeast. It is characterized by short and nearly parallel mountain ranges of monoclinal structure and rarely above 8000 feet elevation. For the most part these mountains are abrupt and denuded of soil except in timbered places. Alluvial soils of many of the valleys and basins that occur throughout the area are valuable for agricultural purposes.

Throughout the Arizona Highlands Region precipitation mostly falls in local torrential showers, and the resultant water erosion is excessive and important. The surface of the region exposes many strata, intrusions, and extrusions, and there are few large uniform areas of interest to dry-farmers, except in the southeastern part where extensive fertile limestone soils are found. The localized precipitation varies greatly from year to year, and over no large area is the average more than sixteen to seventeen inches. Temperatures are generally higher and precipitation lower than in the Colorado Plateaus Province. The entire Arizona Highlands Region must be classed as arid and semi-arid.

CLIMATOLOGY

It is essential that the climatic conditions of Arizona be understood by farmers, since they are not duplicated in any other part of the United States, excepting in adjacent regions of bordering states, and are subject to extreme variations in relatively short distances.

TEMPERATURE

Arizona, in common with all of the region between the Rocky Mountains and the coast ranges, is subject to great variations between minimum and maximum temperatures, the former being relatively low at a given altitude and latitude, and the latter relatively high. The effects of extreme temperatures, however, are not so pronounced as in a humid climate. The wide variation in temperatures of night and day has a decided effect upon plants. Certain sorghums, for example, which will mature in a given number of days in a region having approximately the same maximum temperature as Snowflake fail to ripen at the latter place in a considerably longer time, though they may not be at all injured by frost. Night temperatures of the frost-free season in the higher altitudes of Arizona, while not low enough to directly injure tender plants, are too low to permit proper development throughout a large part of the growing period. Extremely wide local variations are noted: for example, in the Fort Valley Forest Experiment Station, west of Flagstaff and directly at the base of San Francisco Mountain, lower temperatures occur later in spring and earlier in autumn than one thousand feet higher on the mountain side, and the same frost temperature at each of the two points shows less effect on vegetation on the mountain slope than in the valley bottom. Likewise, in places at the base of Cinder Mountain, east of Flagstaff, temperatures at the same elevation vary decidedly. This inconsistency is due to localized atmospheric movement controlled by the abrupt topography.

Furthermore, there is a greater variation between average and extreme dates of the last killing frost in spring and the first in autumn than is ordinarily expected. See Table I. For this reason it is more or less risky to plant crops which demand all of the expected frost-free season for their maturity.

TABLE I. RECORDS OF LAST KILLING FROSTS IN SPRING AND FIRST KILLING FROSTS IN AUTUMN

Station	Length of record	Elevation	Average in autumn	Average in spring	First in autumn	Last in spring
	Years	*Feet*				
Prescott Dry-farm.	6	5008	Oct. 20	May 1	Sept. 22	May 26
Holbrook	8	5069	" 5	" 19	" 17	June 4
Prescott	8	5320	Sept 29	" 21	" 12	" 5
St. John's	8	5650	" 29	" 15	" 25	May 25
Snowflake	4	5600	" 18	June 8	" 5	June 18
Flagstaff	11	6700	" 24	" 7	" 22	" 16
Mesa	16	1244	Dec. 1	Feb. 27	Oct. 21	Apr. 2
Tempe	8	1165	Nov. 24	" 26	" 23	Mar. 3
Phoenix Experiment Station	17	1108	Dec. 6	" 16	Nov. 9	" 31
Phoenix	18	1108	Nov. 27	Mar. 8	Oct. 22	Apr. 19
Peoria	10	1150	Dec. 14	Feb. 24	Nov. 9	Mar. 29
Buckeye	16	980	Nov. 23	Mar. 6	Oct. 22	Apr. 6

ATMOSPHERIC MOVEMENTS

As a whole, Arizona has low wind movements, but in certain localities the topography is responsible for a number of windy days, especially in spring. The Little Colorado drainage area, a funnel-shaped basin 200 miles long and 150 miles wide at the lower end, backed at the source by the White Mountains, and having a gentle slope from side to side, is subject to high atmospheric movements in certain seasons.

In localized areas topographic features make probable frequent recurrence of destructive blast winds. Two high winds, one according to reports a tornado, passed over a portion of Anderson mesa and the upper Willow Valley, the paths being about fifteen miles apart. Three slightly destructive blast winds have occurred at Tucson in as many years, but there are no reasons to suppose that a well defined tornado path exists in any part of the State.

The Sulphur Spring Valley, heading at the base of Graham Mountain, terminates at a much lower elevation some one hundred miles south in Mexico, and has topographic features favorable to considerable atmospheric movements. A low range of hills crossing the Valley near Pearce checks the lower currents somewhat; but, in general, the entire region may be characterized as having fairly high wind movements, especially in spring.

In southwestern Arizona the low hot areas which are adjacent to cooler elevated regions are subject to sudden and rapid wind

movements, especially at changes of season in spring and fall. These winds often carry considerable dust and are unpleasant but not destructive. Table II records the average hourly wind movement as observed for a number of years at various representative localities of the State.

TABLE II. AVERAGE WIND MOVEMENT, MILES PER HOUR

Station	Years of observation	January	February	March	April	May	June	July	August	September	October	November	December	Mean annual
Flagstaff	5	6.0	7.0	9.0	9.0	10.0	9.0	7.0	5.0	7.0	7.0	6.0	7.0	7.4
Fort Grant....	12	6.4	7.3	7.4	8.0	7.5	7.4	6.3	5.9	7.0	6.8	6.7	6.5	6.9
Fort Apache..	9	5.0	6.1	6.8	8.2	7.9	7.7	6.0	5.4	5.8	6.1	5.4	5.1	6.3
Phoenix	18	3.6	4.2	4.7	4.8	5.0	4.8	4.7	4.6	4.3	4.1	3.8	3.6	4.4
Tucson	8	4.7	5.7	5.6	5.9	5.6	5.5	5.1	4.6	4.6	5.6	5.2	4.9	5.2
Yuma	35	6.3	6.8	7.0	7.2	6.8	6.1	6.7	6.1	5.1	5.1	5.7	6.2	6.2

In general there are two precipitation maxima, one in midwinter and one in midsummer. Winter precipitation, which is of greater importance in northeastern Arizona, occurs either as snow or a gentle downfall of rain and penetrates quite completely into the ground. Individual showers usually cover a considerable territory. Summer rains, of primary importance in southern Arizona, occur as local torrential showers often lasting but a few minutes and rarely continuing more than a couple of hours. It is difficult to have these rains penetrate well, since one-half inch of precipitation, occurring in a few minutes, is apt to start a considerable surface runoff, and occasionally more than 75 per cent of the heavier showers is lost in this way. The mean annual precipitation varies with the altitude; but, owing to local topographic features, this variation is usually not in direct proportion. For example, the mean annual precipitation at Tucson, altitude 2425 feet, is slightly greater than at Snowflake, altitude 5644 feet. This is due to the somewhat abrupt southwestern border of the Colorado Plateaus Region. The sudden increase of altitudes causes precipitation of a great deal of moisture from southwestern winds, and it is not until these winds reach a considerably higher altitude that much further precipitation takes place. A second example is that of the Prescott Dry-farm which receives fully two inches less moisture each year than Prescott, about seven miles south, while Jerome Junction, about ten miles north, receives still less. The difference in altitude between

these places is insufficient to account for the variation in precipitation. Table III records the rainfall in these three localities in the summer of 1912.

TABLE III. LOCAL VARIATION OF RAINFALL, 1912

Date	Prescott Elevation 5320 ft.	Prescott Dry-farm Elevation 5008 ft.	Jerome Junction Elevation 4650 ft.
	Inches	*Inches*	
July 13	....	.56	....
" 14	.16	....	....
" 15	....	.02	....
" 16	.98	.11	....
" 17	.16	2.07	....
" 18	.75	.43	....
" 19	.20	.15	....
" 20	.05	.02	....
" 21	.02	....	....
" 24	.23	.30	....
" 25	.85	.60	....
" 26	1.93	.95	....
" 27	.18	....	....
" 28	.11	.40	....
" 29	.22	....	....
" 30	.12	.60	....
" 31	.24	.49	....
Total	6.20	6.70	3.66
Aug. 12	.02	....	....
" 13	.26	.05	.07
" 14	1.00	.11	.10
" 19	....	....	.02
" 22	....	.05	....
" 23	.05	....	.02
" 24	.04	....	.25
" 25	....	....	.07
" 26	.08	....	....
" 27	.27	.35	....
" 28	....	....	....
" 30	....	....	.17
" 31	.37	.02	.02
Total	2.09	.58	.72
Sept. 30	.30	....	.01
Oct. 1	.13	.26	.21
" 2	.31	.17	....
" 3	.03	....	....
" 4	.92	.20	.24
" 5	1.88	.75	.75
" 6	.01	....	.06
" 10	.08	.61	....
" 27	.86	....	....
" 28	....	....	.01
" 29	....	....	.27
Total	4.22	1.99	1.54
Grand Total	12.81	9.27	5.93

A third interesting example of localized precipitation is found in the Sulphur Spring Valley. McNeal, having an altitude of 4150 feet, receives a mean annual precipitation of 15.70 inches; Cochise, altitude 4219 feet, receives 11.41 inches; and Willcox, about the same elevation as McNeal, receives only 10.67 inches. Table IV records mean monthly precipitation, and for convenience in study is grouped into four districts as follows: (1) The Little Colorado Drainage Basin; (2) Other localities above 4000 feet elevation; (3) Localities between 2000 and 4000 feet; (4) Localities below 2000 feet.

While the mean annual precipitation is indicative, the distribution of rainfall is of primary importance. For illustration, individual showers of one-quarter or one-third inch, occurring at intervals of two or three days have no real value, and often necessitate considerable work to preserve a mulch. An inch of precipitation falling thus intermittently may be detrimental; whereas, if the showers had come very close together, or if an inch of precipitation had fallen in one or two showers, the effect would have been beneficial. While an inch of precipitation falling in one hour moistens the soil to some extent, it is largely lost by surface runoff; whereas an inch of precipitation falling over a longer time more completely enters the ground.

The amount of moisture lost by surface runoff is great, often being sufficient to close all traffic for several hours at a time even on main roads. Since so much value is lost in this manner one of the problems of successful farming is proper utilization of floods. In this Arizona Indians are masters. There are thousands of acres within the State which may be irrigated occasionally by these floods. Figures 4, 5, 6, and 7 graphically illustrate the amount and distribution of precipitation at representative Arizona localities.

TABLE IV. PRECIPITATION DATA FOR REPRESENTATIVE ARIZONA REGIONS

Station	Elevation	Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Little Colorado Drainage Basin															
Pinedale	6500	2	.44	1.73	.45	.34	.75	.69	4.07	3.04	.66	2.70	.92	.81	16.60
Showlow	6300	18	1.82	2.03	1.92	.96	.64	.34	2.03	2.15	1.93	1.11	1.32	1.70	17.95
Lakeside	6500	3	1.03	3.01	2.23	.80	.44	.68	6.49	2.42	1.15	2.45	1.10	1.25	23.05
Flagstaff	6907	21	2.91	2.62	2.90	1.33	1.59	.47	2.45	2.89	1.43	1.18	1.61	2.49	23.87
Springerville	6862	3	.33	.82	.29	.25	.18	.51	3.14	2.69	.86	.91	.86	.80	11.64
Alpine	8500	3	.57	1.16	.50	.60	.23	.79	4.49	4.58	1.97	3.90	1.01	2.01	21.81
Snowflake	5644	5	.36	1.01	1.12	.90	.49	.71	2.72	2.22	.73	1.60	.49	.89	13.24
St. John's	5650	11	.61	.23	.53	1.20	.46	.38	1.53	1.82	.86	.20	.03	.45	8.30
Tuba	4500	12	.63	.46	.44	.55	.23	.21	.52	.81	.48	.63	.74	.63	6.33
Holbrook	5069	18	.75	.69	.66	.53	.31	.14	1.41	1.41	.81	.71	.87	.70	8.99
Winslow	4853	8	.41	.64	.44	.22	.23	.38	.40	1.03	.23	.69	.33	2.04	7.04
Taylor	6255	6	.77	1.25	.86	.31	.65	.64	.99	2.33	1.39	.13	.27	.54	10.13
Keam's Canyon	3326	5	1.24	1.07	1.07	.45	.35	.12	.98	1.75	.93	1.35	.85	2.21	12.37
Pinto	5660	4	.71	.95	1.10	.99	.05	.43	1.22	2.33	1.03	.99	1.90	1.20	12.90
Other localities above 4000 feet															
Williams	6750	12	2.00	2.46	1.64	1.07	1.13	.08	2.77	2.64	1.90	1.24	1.71	2.00	20.64
Prescott	5320	18	1.56	1.96	1.71	.82	.55	.24	2.85	3.20	1.05	.78	1.11	1.57	17.40
Seligman	5219	4	1.62	1.67	1.78	.84	.35	T	2.04	1.66	1.24	.66	1.91	1.71	15.48
Ash Fork	5229	..	1.40	1.36	.96	...	...	...	.70	1.46	.90	2.00	.86	.62	10.26
Jerome	4743	12	1.48	2.17	1.76	1.15	.66	.14	2.11	3.35	1.14	1.06	1.60	1.43	18.05
Moccasin	4500	2	2.58	2.83	.52	.81	.11	.41	1.83	1.14	1.07	1.23	1.93	.20	14.66
Kanab (Utah)	4925	3	1.80	1.58	2.59	.90	.79	.26	.94	1.01	.71	.94	1.56	.94	14.02
Grand Canyon	6866	6	1.47	2.42	1.61	.68	1.04	.06	3.59	5.44	2.59	1.67	2.08	2.67	25.32
Natural Bridge	4990	19	2.44	2.45	2.23	1.01	.60	.28	2.36	3.00	1.95	1.36	1.94	2.00	21.62
Prescott Dry-farm	5008	4	1.69	1.41	1.15	.64	.21	.19	3.10	1.97	1.30	1.47	.41	1.88	15.42
Cochise	4219	25	.87	1.18	.71	.24	.27	.15	2.27	2.40	1.31	.63	.61	.77	11.41
Willcox	4164	34	.78	.92	.85	.15	.22	.43	2.03	2.45	.92	.57	.61	.74	10.67
Bowie	3756	43	1.03	1.58	1.11	.16	.23	.52	2.74	2.86	1.15	.63	.66	1.06	13.73
McNeal	4150	..	.13	1.54	1.03	.19	.08	.32	2.73	4.82	1.04	1.26	1.88	.68	15.70
Douglas	3930	20	.87	1.05	.84	.29	.26	.37	3.22	3.41	1.29	1.13	.85	.81	14.39
Bisbee	5500	25	1.14	1.50	1.08	.43	.24	.39	3.71	4.85	1.78	1.09	.81	1.03	18.05
Naco	4579	2	.59	.52	2.36	.09	T	.50	3.57	3.53	1.67	1.16	.98	.65	15.62
Allaire's Ranch	4184	20	.73	.84	.75	.21	.17	.28	2.62	2.60	1.37	.58	.79	.71	11.65

TABLE IV.—*Continued*

Station	Elevation	Years	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Fort Huachuca..	5100	28	1.08	1.27	1.01	.28	.26	.49	3.69	4.22	1.83	.71	1.03	.99	**16.86**
Ft. Apache	5200	42	1.31	1.65	1.46	.81	.54	.52	2.94	3.50	1.60	1.22	1.10	1.47	**18.12**
Bonita	4916	40	1.06	1.16	.84	.34	.27	.39	2.88	2.87	1.57	.85	.71	1.16	**14.10**
Blue	6500	10	1.30	1.70	1.80	.80	.15	.49	3.11	2.98	1.88	1.39	1.53	1.27	**18.40**
Tombstone	4550	17	.77	1.30	.86	.33	.24	.41	3.31	3.61	1.64	.52	.80	.75	**14.54**
Localities between 2000 and 4000 feet															
Benson	3523	33	.53	.72	.52	.16	.12	.31	2.16	2.25	1.05	.67	.38	.48	**9.35**
Tucson	2425	47	.77	.94	.73	.31	.12	.21	2.52	2.52	1.10	.54	.73	1.09	**11.58**
Thatcher	2800	16	.60	.95	.78	.27	.10	.27	1.96	1.75	.98	.71	.91	.80	**10.08**
San Simon.....	3609	26	.44	.46	.70	.11	.15	.11	.82	1.58	.62	.37	.35	.47	**6.18**
Wickenburg	2072	17	1.08	1.13	.64	.51	.17	.02	1.09	1.64	.59	.38	.62	1.42	**9.29**
Kingman	3326	3	1.56	2.00	1.94	.74	.30	.05	.72	1.94	1.02	.72	.52	.75	**12.26**
Columbia	2250	24	1.96	2.49	1.39	.55	.17	.15	2.11	2.41	.79	1.19	1.27	1.53	**16.01**
Dudleyville	2200	25	1.31	1.55	1.03	.52	.36	.26	2.13	2.70	1.23	.92	.96	1.32	**14.29**
San Carlos	2456	31	1.36	1.49	1.15	.39	.26	.17	1.65	2.47	.94	.86	.85	1.28	**12.87**
Globe	3525	16	1.34	1.38	1.61	.58	.31	.26	2.45	2.44	1.43	1.33	1.49	1.60	**16.22**
Ft. Thomas.....	2816	12	.83	1.34	1.02	.32	.55	.25	2.03	2.47	.91	.69	.50	1.29	**12.20**
Indian Oasis....	3000	1½	.38	2.52	.10	.56	.13	1.03	2.89	4.08	.10	2.00	.05	.93	**14.77**
Vail	3241	33	.77	1.02	.73	.37	.16	.25	2.07	2.52	1.08	.56	.52	.68	**10.73**
Duncan	3543	8	.53	1.16	.97	.34	.25	.26	1.34	1.85	1.42	.82	.75	1.48	**11.17**
Nogales	3840	18	1.01	.78	.56	.24	.08	.42	3.03	4.12	1.67	.55	.63	.52	**13.55**
Localities below 2000 feet															
Casa Grande....	1396	34	.71	.63	.54	.19	.05	.14	.76	.93	.50	.33	.59	.69	**6.06**
Maricopa	1173	39	.60	.62	.51	.20	.08	.09	.78	.99	.55	.39	.57	.68	**6.06**
Parker	353	21	.80	.58	.31	.11	.16	.02	.38	.62	.27	.22	.34	.46	**4.27**
Gila Bend.....	737	24	.68	.70	.64	.18	.06	.03	.76	.89	.25	.34	.45	.69	**5.67**
Yuma	141	24	.37	.47	.34	.08	.04	.02	.20	.58	.22	.21	.30	.43	**3.26**
Florence	1493	20	1.01	1.00	1.04	.32	.18	.29	1.48	1.51	.71	.49	.67	1.02	**9.72**
Granite Reef Dam	1372	48	.99	1.24	.82	.42	.15	.10	1.36	1.44	.82	.47	.80	1.32	**9.93**
Tempe	1165	9	.89	1.34	1.24	.59	.10	.14	2.01	1.53	.47	.70	1.06	.94	**11.01**
Sentinel	685	15	.37	.49	.28	.26	.00	.01	.61	.63	.20	.12	.37	.30	**3.64**
Phoenix	1108	38	.78	.87	.62	.33	.11	.07	1.12	.94	.65	.41	.65	.84	**7.39**

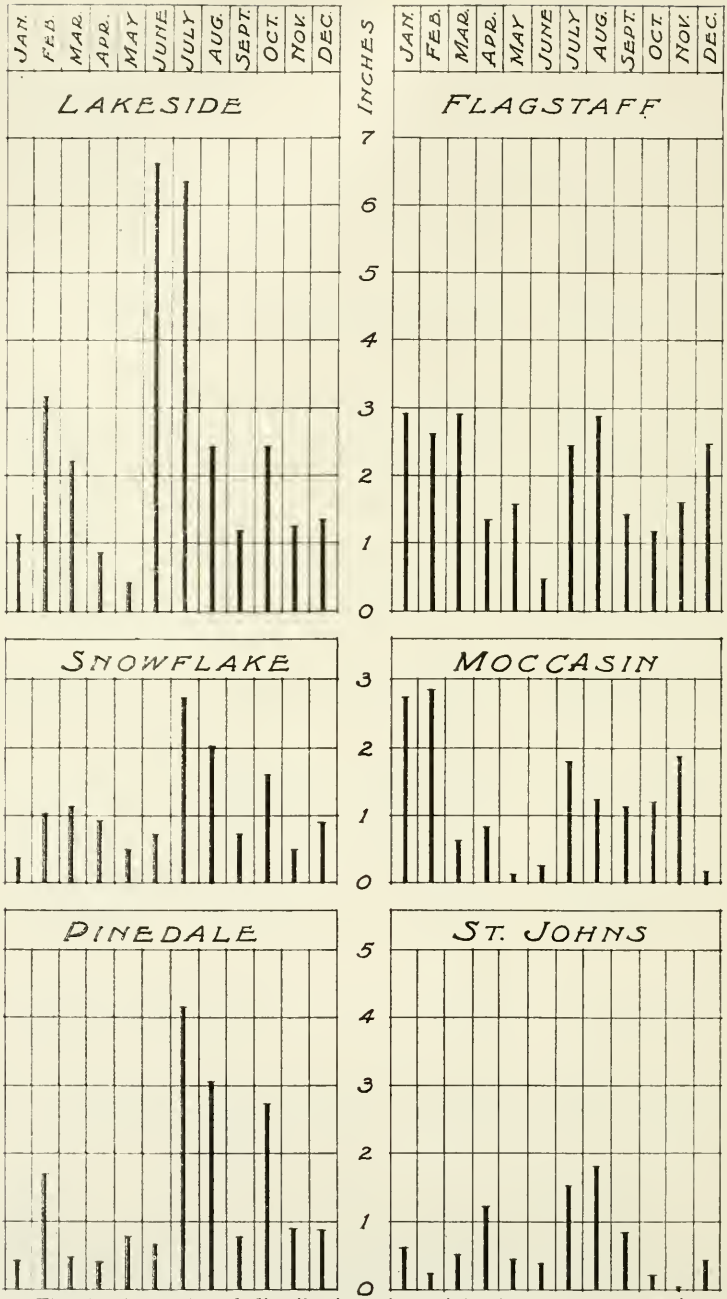

Fig. 1.—Amount and distribution of precipitation at representative Arizona localities.

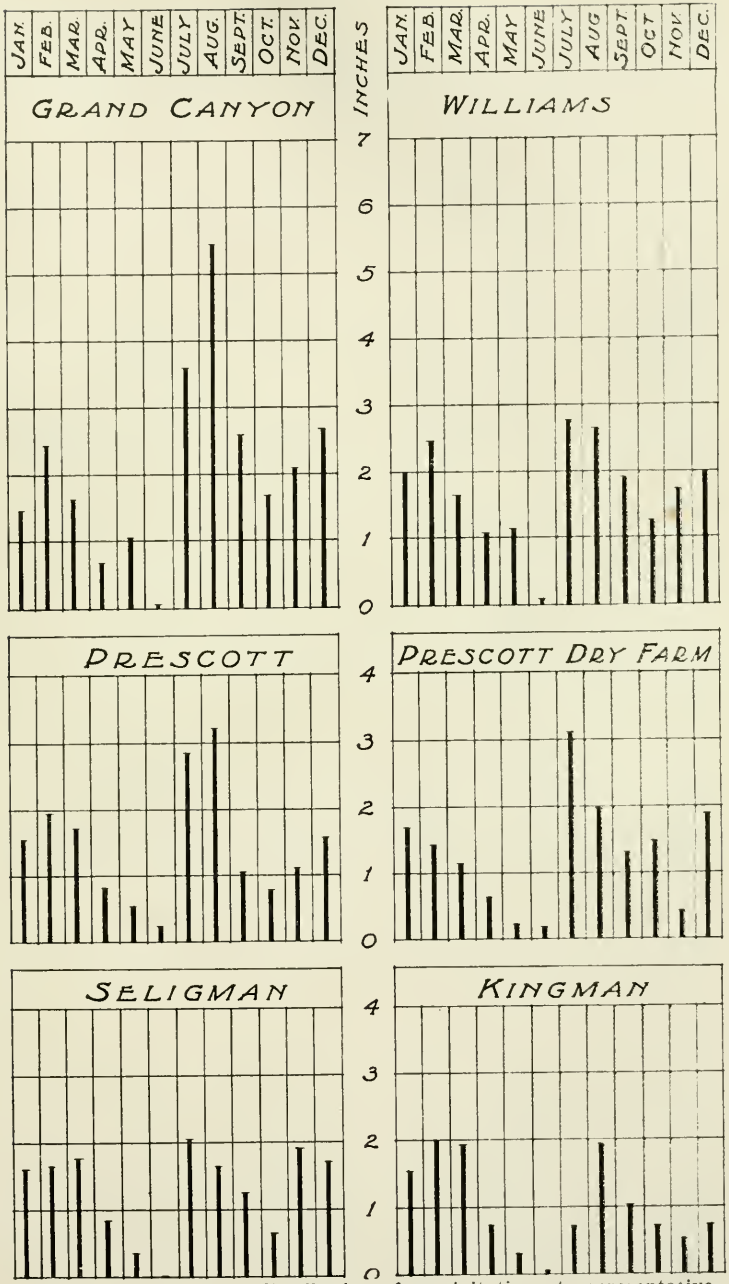

Fig. 5.—Amount and distribution of precipitation at representative Arizona locations.

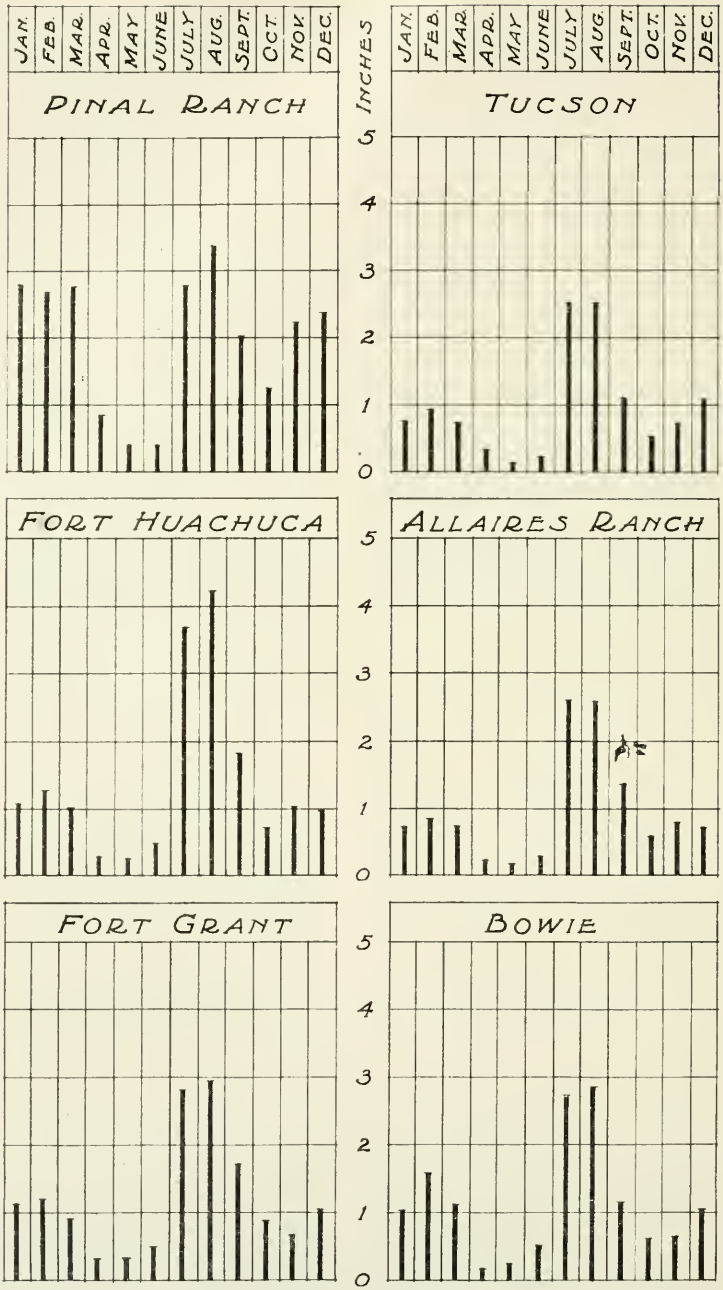

Fig. 6.—Amount and distribution of precipitation at representative Arizona locations.

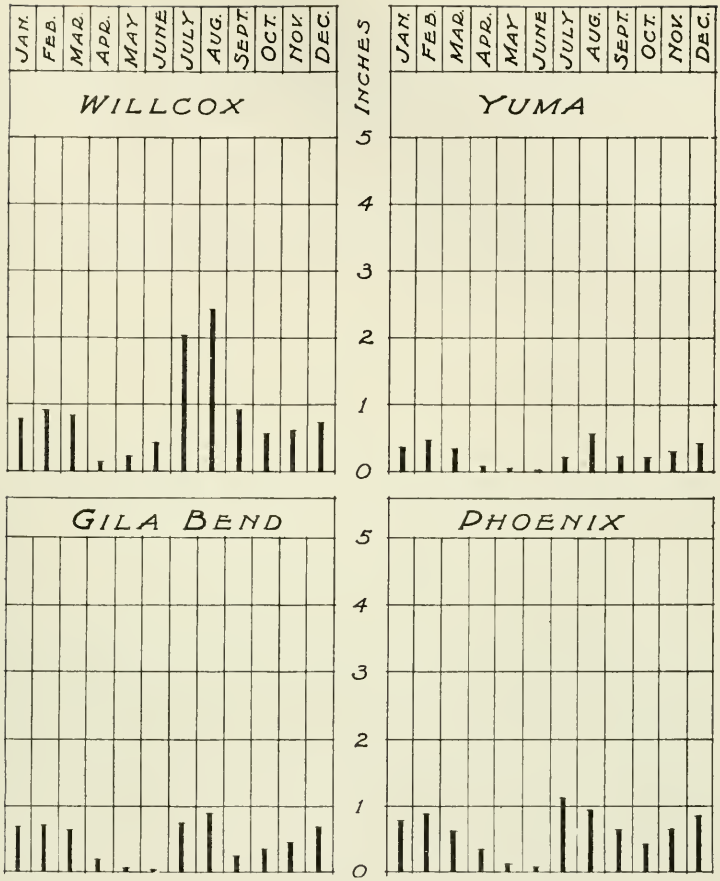

Fig. 7.—Amount and distribution of precipitation at representative Arizona locations.

PRINCIPAL DRY-FARMING REGIONS

LITTLE COLORADO DRAINAGE AREA

While soils of the Little Colorado drainage area are quite variable, they may be divided roughly into four classes: river bottom, first mesa, variegated intermediate, and timber soils. A comparatively large area of fairly uniform soil of each type may be found.

The river bottom soils are deep and very fertile, but often contain excessive amounts of alkali which in some cases render them valueless. Usually river bottom soils occur as clay loams with occasional patches of clay or adobe soils. The fine texture and lack of humus causes them to crust and bake during dry weather, and often they are hard to till except when they contain the optimum percentage of moisture. Being deep and fine, soils of this type retain moisture very well, though water penetration is not rapid.

Soils of lighter texture are found in extensive areas, notably at Woodruff, Winslow, and St. Johns, and the broad mesas north of Holbrook and Adamana. These lands, classed as first mesa soils, are easier to till because of their lighter texture, and are more readily permeable but less retentive of moisture. No alkali is found in the first mesa soils, which have resulted from the decomposition of red and brown sandstones. The fertility is not so high as that of the bottom lands.

The variegated intermediate soils occur at the mouths of numerous draws and arroyos, and in little valleys along small creeks between low rolling hills. Because of their diverse origin variegated intermediate soils are not uniform and usually occur in small tracts, notably areas of silt soil of considerable depth in the Dry Lake region, at Cottonwood Wash, and on Silver Creek, all in the vicinity of Snowflake. Soils on the higher elevations in this vicinity are too shallow for dry-farming, usually being from one to four feet deep. Thus, the large, gradually rising region extending southward from Holbrook to Shumway is characterized by a shallow soil, only the wider valleys containing soil adapted to dry-farming. Except for grayish brown silt soils near Snowflake the prevailing color is reddish brown as a result of decomposition of sandstone capped by a thin veneer of limestone. Mechanical and chemical analyses of

soil samples from the Snowflake Dry-farm, which are typical of the valley soils of this region, are reported in Tables V and VI. The mechanical analysis shows a high percentage of clay and silt in the fourth foot, and a high percentage of very fine sand and low percentage of clay in the eighth foot. The soil is a fine sandy loam containing sufficient clay to insure lasting fertility, and enough silt and very fine sand to prevent baking. Soil of this type is easily tilled and allows the economical use of moisture. The chemical analysis indicates a fairly rich soil, free from injurious amounts of alkali.

Fig. 8.—Ranch in open park in Northern Arizona forest, 6500 feet elevation.

TABLE V. MECHANICAL ANALYSIS OF SOIL FROM SMITH FIELD, SNOWFLAKE DRY-FARM

Sample	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	%	%	%	%	%	%	%
1st foot	0.4	4.3	4.8	27.7	23.9	21.6	17.2
2nd "	.2	2.6	3.5	29.4	25.1	22.3	16.7
3rd "	.0	1.1	1.3	15.3	27.6	34.4	20.4
4th "	.0	.4	.6	13.0	23.0	40.6	22.4
5th "	.0	.5	.6	17.7	31.0	32.4	17.6
6th "	.5	2.6	2.7	21.8	22.9	28.3	21.0
7th "	.0	1.1	1.6	25.0	32.0	22.9	17.4
8th "	.2	.7	1.1	24.0	38.6	20.1	15.0
Average ...	.16	1.66	2.02	21.73	28.01	27.82	18.46

Note: The separates referred to in the mechanical analyses given in this bulletin are those of the U. S. D. A. Bureau of Soils: Fine gravel, diameter 2 to 1 millimeters; coarse sand, 1 to 0.5 mm.; medium sand, 0.5 to 0.25 mm.; fine sand, 0.25 to 0.10 mm.; very fine sand, 0.10 to 0.05 mm.; silt, 0.05 to .005 mm.; clay, less than 0.005 mm.

TABLE VI. CHEMICAL ANALYSIS OF SOIL FROM SMITH FIELD, SNOWFLAKE DRY-FARM

Composite sample	Acid insoluble	Potash (K_2O)	Phosphoric acid (P_2O_5)	Lime (CaO)	Nitrogen (N)	Humus	Alkali		
							Soluble solids dried at 110° C.	Chlorides as NaCl	Calcium and magnesium sulphates and chlorides as $CaSO_4$
	%	%	%	%	%	%	%	%	%
1st 4 feet	84.470	.517	.089	2.987	.037	.079	.123	.004	.033
2nd 4 feet	82.959	.834	.075	3.533	.055	.540	.128	.004	.065
Avg. 8 feet	83.714	.675	.082	3.260	.046	.310	.128	.004	.049

Note: The chemical analyses of dry-farming soils reported in this bulletin refer to that portion of the soil soluble in hydrochloric acid, 1.115 sp. gr., according to the methods of the Association of Official Agricultural Chemists. The alkali determinations refer to the salts soluble in water when 50 grams of soil are digested with 1000 C.C. water for ten hours on the water bath. Arizona Agricultural Experiment Station Twenty-fourth Annual Report, p. 275.

Extensive areas of agricultural lands are found in open parks and on the larger flats of the timber belt. These soils are largely decomposed lava of very fine texture in the bottoms, and coarse and gravelly on the slopes.

The best agricultural soils within the timber belt are loams of medium texture, though coarser types produce well under the relatively heavy precipitation of the region. These soils are fairly permeable and retain water very well with reasonable cultivation. The

bottom lands are of fine texture and lack organic matter. Water penetration is slow but moisture is retained efficiently. Adobe soils also are found in the bottoms. They are low in humus and nitrogen, baked in the dry season, and are difficult to till. They are relatively fertile, however, and if plowed in the fall and exposed to freezing and thawing in winter are handled with less difficulty. The most interesting lava soils within the timber belt are found near Lakeside, east and north of Showlow Creek and around Flagstaff, but soils little affected by lava occur at Scott's Flat, the mesa southwest of Showlow, the Linden vicinity, and the Pinedale region. Table VII records a chemical analysis of soil from a farm near Linden, which had been under cultivation for two years. It shows less nitrogen and humus than the lava soils around Flagstaff but contains nearly three times as much lime.

TABLE VII. CHEMICAL ANALYSIS OF SOIL FROM NEAR LINDEN

Composite sample	Acid insoluble	Potash (K_2O)	Phosphoric acid (P_2O_5)	Lime (CaO)	Nitrogen (N)	Humus	Alkali		
							Soluble solids dried at 110° C.	Chlorides as NaCl	Ca and Mg sulphates and chlorides as $CaSO_4$
	%	%	%	%	%	%	%	%	%
1st 4 feet	84.983	.402	.097	3.258	.052	.700	.128	.004	.000
2nd 4 feet	84.100	.500	.105	3.233	.028	.750	.140	.012	.022
Avg. 8 feet	**84.541**	**.451**	**.101**	**3.245**	**.040**	**.725**	**.134**	**.008**	**.011**

Another type, a scoriaceous soil, occurs on slopes of volcanic cones and ridges. It is quite coarse and porous, absorbing water readily and giving it up easily. This soil is composed of a mixture of slag and pumice-like detritus, and is red, gray, or yellow in color. The cinder soil east of San Francisco Mountain is worthless for agricultural purposes and is barren, save for a few quick growing annuals which utilize moisture from summer rains.

In Tables VIII and IX are recorded mechanical and chemical analyses of a typical lava soil sample, taken from a field at Cliffs in which grain and potatoes had been grown for five or six years. The lava soil contains more coarse material than the soil from Pipe Springs Valley or from Linden, but the larger amount of clay and silt insures lasting fertility. The percentages of nitrogen and humus are relatively high, and there is a medium phosphoric acid content.

TABLE VIII. MECHANICAL ANALYSIS OF TYPICAL LAVA SOIL FROM CLIFFS

Sample	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	%	%	%	%	%	%	%
1st foot	3.0	9.4	6.3	15.0	12.3	40.8	13.2
2nd "	1.2	9.8	4.0	14.4	14.0	41.9	14.5
3rd "	5.0	10.1	5.0	15.2	12.3	39.0	13.2
4th "	1.6	3.1	1.4	6.9	15.9	52.3	18.8
5th "	4.2	5.9	2.9	9.4	11.5	47.7	18.2
6th "	1.6	5.2	3.0	11.9	16.7	47.6	14.2
7th "	1.9	7.6	4.8	17.0	17.5	40.9	10.6
8th "	3.8	10.3	6.1	20.8	17.9	30.5	11.0
Average ...	2.79	7.67	4.19	13.82	14.76	42.59	14.21

TABLE IX. CHEMICAL ANALYSIS OF TYPICAL LAVA SOILS FROM CLIFFS

Composite sample	Acid insoluble	Potash (K_2O)	Phosphoric acid (P_2O_5)	Lime (CaO)	Nitrogen (N)	Humus	Alkali		
							Soluble solids dried at 110° C.	Chlorides as NaCl	Ca and Mg sulphates and chlorides as $CaSO_4$
	%	%	%	%	%	%	%	%	%
1st 4 feet	80.112	.413	.083	.962	.061	1.160	...	...	...
2nd 4 feet	70.596	.892	.075	1.265	.108	.560	...	...	...
Avg. 8 feet	75.354	.652	.079	1.113	.084	.860	...	...	...

VALLEYS OF WESTERN COLORADO PLATEAUS PROVINCE AND NORTHERN ARIZONA HIGHLANDS REGION

The area described below extends westward from the Arizona Divide, which diverts drainage from the Little Colorado on the east and north to the Colorado River, and southward from Fredonia to Wickenburg. There are wide variations in soil, temperature, and precipitation. The larger valleys of importance include Lonesome, Big Chino, Little Chino, Aubrey, Hualpai, Detrital, Sacramento, and Big Sandy. The smaller interesting valleys are Williamson, Skull, Kirkland, Peeples, and McMullen, which are occupied mostly by cattle ranches.

LONESOME AND LITTLE CHINO VALLEYS

Lonesome and Little Chino Valleys, having the same topographic soil and climatic conditions, and merging into one another,

should be considered together. Probably 150,000 acres suitable for dry-farming are included. Granite Mountains on the south and west, and the Black Hills on the east and north almost completely enclose these valleys. The two principal drainage streams, Granite and Willow Creeks, flow north and east, and in the rolling topography of the valleys numerous floodwater courses have been formed. All drainage courses converge near Del Rio, forming one of the main tributaries of the Verde River.

Rapid water erosion takes place in the flood season, and meandering of the larger streams causes depositions of great quantities of sediment on either side of the floor of the valleys forming a very fertile silt soil. A fairly coarse loam is found on the first mesa immediately adjacent to the creek bottoms, and a gravelly loam occurs on frequent knolls in the valleys, though neither of these loams is as fertile as the silt soil of the bottoms. All three soil types are found on the Prescott Dry-farm. Tables X and XI give the mechanical and chemical analyses of the silt soil deposited in limited areas along the stream courses of the Little Chino and Lonesome Valleys. It contains a large percentage of nitrogen and humus, and is very fertile. Tables XII and XIII give the mechanical and chemical analyses of the intermediate loam on the Prescott Dry-farm. The sample is typical of the prevailing soil type of the region. The high percentages of silt and clay classify this soil as a fine loam. It is permeable and retains moisture quite well. The percentages of nitrogen and humus are fairly low, though the soil shows relatively high fertility.

TABLE X. MECHANICAL ANALYSIS OF SOIL FROM BOTTOM LAND, PRESCOTT DRY-FARM

Sample	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	%	%	%	%	%	%	%
1st foot	7.4	15.8	7.6	20.2	18 0	22.9	8.0
2nd "	3 9	10 4	4.2	14 7	23.2	31.9	11.3
3rd "	7.6	14.8	6.4	21 3	20 5	21.5	8.1
4th "	5 9	15 4	7.2	22 5	20.4	20.8	7.6
5th "	4.5	8.6	4.1	17.1	22.6	30.8	11.8
6th "	11.2	23.0	8.2	23.1	14.4	13.1	6.6
Average ...	6.75	14.7	6.28	19.81	19.85	23.5	8.90

TABLE XI. CHEMICAL ANALYSIS OF SOIL FROM BOTTOM LAND, PRESCOTT DRY-FARM

Composite sample	Acid insoluble	Potash (K_2O)	Phosphoric acid (P_2O_5)	Lime (CaO)	Nitrogen (N)	Humus	Alkali		
							Soluble solids dried at 110° C.	Chlorides as NaCl	Ca and Mg sulphates and chlorides as $CaSO_4$
	%	%	%	%	%	%	%	%	%
1st 4 feet	80.820	.532	.190	1.650	.085	1.400	0.192	.012	.044
2nd 4 feet	84.917	.430	.164	1.320	.063	1.000	0.100	.008	.011
Avg. 8 feet	82.868	.481	.177	1.485	.074	1.200	.146	.010	.027

TABLE XII. MECHANICAL ANALYSIS OF INTERMEDIATE LOAM, PRESCOTT DRY-FARM

Sample	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	%	%	%	%	%	%	%
1st foot	4 0	6.4	2.0	5.0	17.4	48.3	16.9
2nd "	5.1	7.6	2.8	6.6	12.6	33.4	31.7
3rd "	4 0	7.9	3.0	8.5	12.4	35.1	29.2
4th "	7.6	15.6	7.0	16.6	10.9	24.6	17.4
5th "	5.0	12.9	6.8	20.7	11.6	26.6	16.7
6th "	11 2	13.8	5.2	13.6	12.2	26.4	17.5
7th "	2.4	3.2	1.0	4.4	16 2	52.2	20.6
8th "	8.4	17.9	7.6	18 0	15.0	22 8	10.4
Average ...	5.96	10.66	4.42	11.67	13.53	33.67	20.05

TABLE XIII. CHEMICAL ANALYSIS OF INTERMEDIATE LOAM, PRESCOTT DRY-FARM

Composite sample	Acid insoluble	Potash (K_2O)	Phosphoric acid (P_2O_5)	Lime (CaO)	Nitrogen (N)	Humus	Alkali		
							Soluble solids dried at 110° C.	Chlorides as NaCl	Ca and Mg sulphates and chlorides as $CaSO_4$
	%	%	%	%	%	%	%	%	%
1st 4 feet	80.059	.395	.328	1.760	0.044	.600	.148	.012	.022
2nd 4 feet	80.863	.510	.209	1.457	.013	.310	.148	.016	.044
Avg.8 feet	80.461	.452	.268	1.608	.028	.455	.148	.014	.033

The native vegetation consists of gramas, six weeks' grass, and scrub oak. Water for domestic purposes may be obtained at depths ranging from 40 to 50 feet in the center of the valleys, and from 300

to 350 feet at higher elevations. Excellent dam sites are available with sufficient drainage areas to allow the irrigation of possibly 15,000 or 20,000 acres. Precipitation varies from twelve to fifteen inches annually.

BIG CHINO VALLEY

The Big Chino Valley, about seventy miles long and an average of seven miles wide, joins the Little Chino on the north and slopes towards the northwest. The soil is a fine sandy loam, largely of granitic origin, and is somewhat similar to that of the first mesas of Lonesome and Little Chino Valleys.

No precipitation records are available, but the average annual rainfall is probably between twelve and fifteen inches. Apparently, there is ample underground water near the surface for domestic use and a supplemental irrigation supply. A dam site at the upper end of the Valley, subjacent to a large drainage area, makes irrigation of a considerable acreage feasible.

AUBREY BASIN

Aubrey Basin, forty miles long and an average of ten miles wide, lies between Aubrey Rim on the east, Yampai Cliffs on the west, the Santa Fe Railroad on the south, and the Grand Canyon on the north. Drainage is toward the south with no outlet, and there are no water courses of importance in the Basin. The elevation in the center of the valley is about 5200 feet. The soil is a fine loam resulting from decomposition of red sandstones and gray limestones. In the center of the valley the soil is probably twenty feet deep, while near the edges it is only two or three feet deep.

The basin is mostly covered with a growth of native grasses, including grama and galleta, but barren spots are found where the grasses probably have been killed out by overgrazing. In these places the soil is shifted badly by winds. The average annual precipitation is probably about fifteen inches. Groundwater is far below the surface. Along the Santa Fe Railroad a small quantity of water is obtained at a depth of 1200 feet; while a strong flow, which rises to within 1000 feet of the surface, is found at a depth of 1600 feet. In the center of the valley a well 680 feet deep furnishes a fairly large quantity of water of excellent quality.

HUALPAI VALLEY

Hualpai Valley, approximately sixty miles long and twenty-five miles wide, extends in a north and south direction and lies immediately west of Peacock and Music Mountains. Except at the north end, it is an undrained basin. Accumulation of floodwater in the center of the basin forms Red Lake, a big muddy flat except during the few weeks of flood season. The valley floor is approximately 3000 feet above sea level, and is surrounded by abrupt mountains on either side. The only stream of importance is Truxton Creek which is dry most of the year.

The soil is a light loam. "Caliche" appears in places but, in general, the soil depth is satisfactory. In the center of the Valley there is considerable soil movement by wind. The native vegetation consists of grama and galleta grasses.

At Kingman, located in the low hills on the west border of the Valley, the average annual precipitation for three years was 7.65 inches, which is insufficient for dry-farming. Underground water may be obtained only at great depths. A well sunk to a depth of 700 feet near the head of the Hualpai Wash failed to go through the top stratum of rock debris. Storage of the water of Truxton Creek, which does not seem feasible, appears to be the only method by which Hualpai Valley can be reclaimed for agricultural purposes.

BIG SANDY VALLEY

Big Sandy Valley lies south of Hualpai Valley beyond Peacock Mountains and Hualpai Peak. Aquarious Cliffs and Aquarious Mountains form the eastern boundary and Aubrey Hills the western. The elevation at Hackberry on the northern border is 3552 feet, and the slope southward is quite abrupt. The Valley is drained by Big Sandy Wash and its tributaries, White Cliff, Trout, Abapuk, Spencer, and Sycamore Creeks and Deluge Wash, all of which are dry most of the year. The soil is largely decomposed granite and in many places is shallow. The average annual precipitation is probably from six to eight inches. Little is known concerning the groundwater supply, but it is probably limited and far below the surface.

DETRITAL AND SACRAMENTO VALLEYS

Directly west of Hualpai and Big Sandy Valleys, extending north and south from Williams Canyon to the Colorado River, are the Detrital and Sacramento Valleys. Because of similarity of geographical and agricultural conditions these Valleys are considered together. They are approximately 130 miles long and from five to fifteen miles wide. About midway occurs a divide which diverts drainage northward through Detrital Wash into the Colorado River near Stone Ferry, and southward through Sacramento Wash to Yucca, thence westward around the end of the Black Mesa into the Colorado River near Mellon. North of the Grand Canyon the depression continues in the valley of the Virgin River. The center of Detrital and Sacramento Valleys is probably about 3400 feet above sea level. The southern half slopes more abruptly than the northern, and the altitude at Yucca is approximately 1800 feet.

Precipitation probably averages six to eight inches annually. The underground water is very deep, and wells must be sunk approximately 1000 feet to obtain small amounts for domestic use. The diversion of floods or their storage for supplemental irrigation is feasible in some places. Climatic features of the southern end of Sacramento Valley adapt the region to the growth of sub-tropical crops wherever the water problem can be satisfactorily solved.

VALLEYS NORTH OF THE GRAND CANYON

PIPE SPRINGS VALLEY

Pipe Springs Valley extends north and south for approximately thirty miles, has a width of approximately twelve miles, and lies between Vermillion Cliffs on the east and a local fault line of Antelope Valley on the west. The northern and southern boundaries are indefinitely determined, the former being a short, abrupt rise in Short Creek Valley, and the latter a gradual slope to Kanab Creek. The soil of the eastern half of the Valley is mostly decomposed sandstone, while in the center and in the western half there is a considerable mixture of disintegrated limestone. Throughout the Valley the soil is deep, uniform, fairly fertile, and easy to till, but is shifted somewhat by winds. The Valley derives its name from water piped from springs in the Vermillion Cliffs. There are no data concerning the groundwater supply, but from appearances

it is far below the surface. Precipitation at various points averaged about 14.5 inches in 1914. About 300,000 acres of land in this valley are adapted to dry-farming, but reclamation will probably be restricted to the area which can be operated by settlers obtaining their domestic water supply from Pipe Springs. Mechanical and chemical analyses of a sample of soil from Pipe Springs Valley are reported in Tables XIV and XV. It is a very fine sandy loam characteristic of the region, easily cultivated, and shifted but little by winds. The percentage of clay increases in the deeper samples, and the soil appears to have lasting fertility. It is free from alkali in injurious amounts, fairly well supplied with nitrogen and humus, and rich in lime. This soil closely resembles that of the Southern Utah Experiment Farm at St. George.

TABLE XIV. MECHANICAL ANALYSIS OF SOIL FROM PIPE SPRINGS, NORTH OF THE GRAND CANYON

Sample	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	%	%	%	%	%	%	%
0-15 inches	0.0	0.1	0.3	17.5	46.5	26.8	8.8
15-30 "	.0	.5	.4	10.3	54.7	29.1	5.1
30-45 "	.0	.0	.1	8.0	30.4	44.9	16.3
45-60 "	.0	.0	.1	9.8	43.1	33.4	13.4
60-75 "	.0	.1	.7	10.3	34.6	35.2	19.1
Average ...	.0.0	0.1	0.3	11.1	41.8	33.9	12.5

TABLE XV. CHEMICAL ANALYSIS OF SOIL FROM PIPE SPRINGS, NORTH OF THE GRAND CANYON

Composite sample	Acid insoluble	Potash (K_2O)	Phosphoric acid (P_2O_5)	Lime (CaO)	Nitrogen (N)	Humus	Alkali		
							Soluble solids dried at 110° C.	Chlorides as NaCl	Ca and Mg sulphates and chlorides as $CaSO_4$
	%	%	%	%	%	%	%	%	%
1st 4 feet	76.144	.343	.128	5.170	.028	.480	...	...	...
2nd 4 feet	75.492	.835	.112	5.733	.036	.660	...	...	...
Avg. 8 feet	75.818	.589	.120	5.452	.032	.570	...	...	...

SHORT CREEK BASIN

This basin, immediately north of Pipe Springs Valley, is named from a creek which originates from springs in the Vermillion Cliffs and sinks in the sand at a place about three miles from its source. The soil is similar to that of Pipe Springs Valley. Native vegetation consists of a good growth of white sage, grama grass, and occasional patches of bunch grass. The construction of a submerged dam across Short Creek, successful operation of which would make possible the irrigation of 4000 or 5000 acres, is apparently feasible.

ANTELOPE VALLEY

Antelope Valley, named from Antelope Springs, which rise at its northern boundary, continues south and west from Pipe Springs and Short Creek Valleys and extends in a north and south direction for forty miles with an average width of about twelve miles. It contains about 350,000 acres, and has soil and climatic conditions similar to Pipe Springs Valley.

HURRICANE VALLEY

Hurricane Valley is separated from Antelope Valley by Hurricane Ledge, a red sandstone fault escarpment, which forms its eastern boundary. The soil is similar to that of Pipe Springs Valley, but it is probably not adapted to dry-farming because of the low precipitation and relatively high temperatures.

HOUSEROCK VALLEY

Houserock Valley, about thirty-five miles long and six miles wide, is bounded on the north by abrupt cliffs in southern Utah, on the east by the Vermillion Cliffs, on the west by Kaibab Plateau and on the south by the Colorado River. Soils of the eastern portion are of red sandstone origin and relatively infertile, while those of the western side are from limestone. "Caliche" is found in many places, and the depth of soil is varied and generally unsatisfactory for water storage. The native vegetation is not uniform, though it furnishes considerable winter grazing for stock pastured in summer on the Kaibab Forest Reserve. The only buffaloes in the State are found in this Valley. There are no data concerning either the groundwater or precipitation, but the practicability of reclamation by dry-farming is questionable.

KAIBAB FOREST RESERVE

The Kaibab Plateau is a large region capped with surface soil of limestone origin. The maximum elevation is about 9000 feet. The annual precipitation probably averages more than twenty inches, and mostly sinks into subterranean courses which reappear as springs, one of the largest forming Bright Angel Creek which flows into the Colorado River about 2000 feet below the canyon rim. Numerous small drainage courses run through the northern and western parts of the Reserve, chief of which is Tenney's Gulch, which empties into Kanab Creek. Summit Valley, one of the principal agricultural areas of the north end of the plateau, merges into Telegraph Flat which is continued in the area east of Kanab along Johnson Run. Numerous small parks of fifty to two hundred acres occur at various places on the plateau, but elevations of 7000 to 9000 feet render dry-farming somewhat precarious. Precipitation falls largely as snow, and the frost-free season is short.

Reclamation by dry-farming in this region is feasible, not so much on the plateau proper, as in the lower valleys bordering the plateau, such as Kanab Creek Valley and Johnson Run. A successful dry-farm on White Sage Flats, sixteen miles southwest of Fredonia, has been operated since 1910, and has satisfactorily produced wheat, rye, barley, potatoes, beans, and corn. Telegraph Flat, slightly east of north of White Sage Flat, offers a considerable area of similar soil. On the east side of Kanab Creek near Fredonia, somewhat extensive areas of dry-farm lands have been successfully operated for many years. In this vicinity the soils are deep fine loams, except in small basins where they are quite adobe. Alkali is frequently encountered both in the soil and in the underground water. About 100 acres near Fredonia with irrigation have produced good crops of alfalfa, small grains, corn, and deciduous fruits.

Throughout the region there are excellent opportunities for a combination of livestock and dry-farming where the summer range of the Kaibab Forest Reserve can be supplemented with dry-farmed feeds in winter.

VALLEYS OF SOUTHEASTERN ARIZONA

At elevations of 3500 to 5000 feet large areas of dry-farm lands are found in valleys of the southeastern part of the State. Chief

among these is Sulphur Spring Valley, containing approximately 1,000,000 acres.

The soil is a fertile decomposed limestone, and "caliche" appears in many places. A large alkali flat lies east of Willcox and Cochise, and alkali spots, in the vicinity of Whitewater and throughout the southern end of the Valley, make reclamation of a large part of the area by dry-farming impracticable. Considerable agricultural development has occurred since 1907. In the valley proper, underground water is usually found at less than fifty feet depth and often in quantities sufficient to make irrigation with pumped water practicable. A small acreage in the vicinity of Whitewater is reclaimed in this way. On the first mesas of the valley the water table is from 75 to 200 feet below the surface but the soil is often considered superior to the lower lands for dry-farming.*

Farming conditions in San Simon Valley are comparable to those of Sulphur Spring Valley. Flowing artesian wells have been developed near San Simon; and near Bowie artesian water has risen near enough to the surface to make pumping for irrigation feasible.

The upper San Pedro Valley contains a large acreage of dry-farming lands similar to Sulphur Spring and San Simon Valleys. Intermittently successful dry-farming has been carried on for about ten years.

In general the soils of the three valleys are loams and sandy loams. They are quite fertile and well supplied with lime. Water penetrates them readily and is quite efficiently retained. The soil samples of which the mechanical and chemical analyses are reported in Tables XVI and XIX are from the Sulphur Spring Valley Dry-farm near Cochise, and are representative of the soils of the three valleys. The bottom land soil reported in Tables XVI and XVII is a loam with a coarse textured stratum at the fifth foot, which hinders the rise of capillary moisture from below. The fine texture of the surface foot retards water penetration, especially that of light summer showers. For these reasons many farmers prefer the sandier mesa soils. The bottom lands contain fair quantities of nitrogen and humus in the first four feet, but the lower four feet are deficient in these materials. Potash, phosphoric acid, and lime are present in ample amounts. The lighter type of soil is repre-

*For a detailed report on geologic and soil conditions in Sulphur Spring Valley, see Paper No. 320 U. S. Geological Survey, "Water Resources of the Sulphur Spring Valley."

sented by the sample of fine sandy loam from the Sulphur Spring Valley Dry-farm reported in Tables XVIII and XIX. It absorbs water readily and with cultivation retains moisture well. The large amount of lime is due to the presence of a calcareous hardpan. This soil is not so fertile as the bottom lands reported in Table XVII.

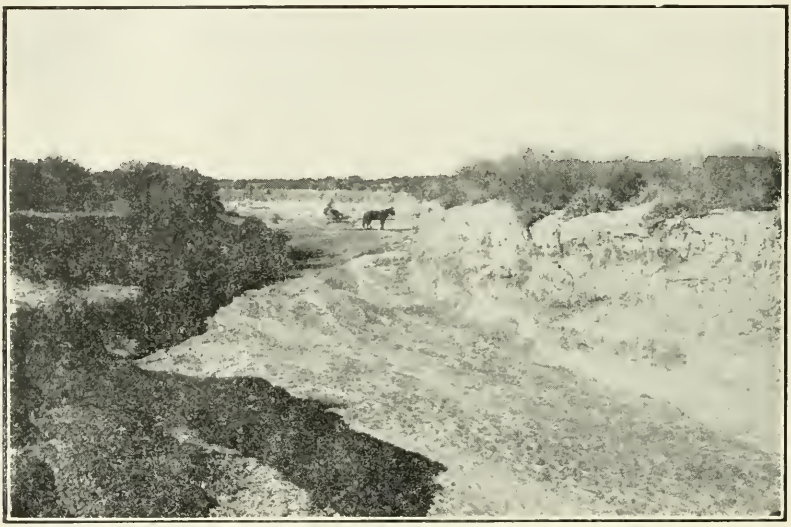

Fig. 9.—San Simon Wash near Solomonville, Arizona.

TABLE XVI. MECHANICAL ANALYSIS OF BOTTOM SOIL, SULPHUR SPRING VALLEY DRY-FARM

Sample	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	%	%	%	%	%	%	%
1st foot	0.9	2.6	1.4	7.4	13.6	48.3	25.7
2nd "	2 8	5.0	2.1	9 8	15.2	38.6	26.4
3rd "	4.5	9.5	4.0	16.5	17.1	28.8	19.8
4th "	6.8	10 3	3.7	16 0	20.3	24.9	17.8
5th "	12.0	13.5	5.1	16 0	11.8	25.3	16.4
6th "	7.0	9.6	4.2	12 9	9.6	40.1	16.6
7th "	6.1	10.1	4.5	15 0	12.8	35.3	16.1
8th "	9.5	12.3	5.1	16.8	14.9	26.1	15.2
Average ...	6.2	9.11	3.76	13.8	14.41	33.42	19.25

TABLE XVII. CHEMICAL ANALYSIS OF BOTTOM SOIL, SULPHUR SPRING VALLEY DRY-FARM

Composite sample	Acid insoluble	Potash (K_2O)	Phosphoric acid (P_2O_5)	Lime (CaO)	Nitrogen (N)	Humus	Alkali		
							Soluble solids dried at 110° C.	Chlorides as NaCl	Ca and Mg sulphates and chlorides as $CaSO_4$
	%	%	%	%	%	%	%	%	%
1st 4 feet	80.461	.429	.121	1.196	.065	1.280	0.136	.008	.087
2nd 4 feet	70.295	.465	.127	2.420	.023	0.510	0.100	.004	.087
Avg. 8 feet	75.378	.447	.124	1.808	.044	.895	.118	.006	.087

TABLE XVIII. MECHANICAL ANALYSIS OF LIGHTER TYPE OF SOIL, SULPHUR SPRING VALLEY DRY-FARM

Sample	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	%	%	%	%	%	%	%
1st foot	6.6	13.0	5.4	20.5	15.9	24.1	14.3
2nd "	11.0	11.9	4.6	16.4	13.9	25.0	17.0
3rd "	11.1	15.1	5.4	18.6	13.8	23.9	12.1
4th "	9.5	14.9	6.6	24.8	14.6	19.4	10.2
5th "	12.4	14.3	5.9	21.6	13.2	21.9	10.6
6th "	10.8	9.3	2.9	10.1	10.8	35.0	21.1
7th "	5.4	8.1	3.5	13.1	13.9	38.1	17.7
8th "	4.8	9.7	4.3	13.5	14.0	32.8	20.8
Average ...	8.95	12.03	4.82	17.32	13.76	27.52	15.47

TABLE XIX. CHEMICAL ANALYSIS OF LIGHTER TYPE OF SOIL, SULPHUR SPRING VALLEY DRY-FARM

Composite sample	Acid insoluble	Potash (K_2O)	Phosphoric acid (P_2O_5)	Lime (CaO)	Nitrogen (N)	Humus	Alkali		
							Soluble solids dried at 110° C.	Chlorides as NaCl	Ca and Mg sulphates and chlorides as $CaSO_4$
	%	%	%	%	%	%	%	%	%
1st 4 feet	84.894	.487	.064	2.048	.059	.540	.132	.004	.011
2nd 4 feet	59.831	.394	.083	13.062	.020	.360	.180	.008	...
Avg. 8 feet	72.362	.440	.073	7.555	.039	.450	.156	.006	.005

INDIAN AGRICULTURE IN ARIZONA

The Indians of Arizona, numbering from 40,000 to 45,000, have contributed very materially to agriculture in the State. Dry-land crop varieties, which have been grown by them for an indefinite period, are among the most promising; and their cultural practices, with some modifications, are the bases of successful dry-farming in Arizona. The total area within the State at present set aside as Indian Reservations is about 17,500,000 acres. According to careful estimates it is possible to irrigate nearly one-quarter million acres of these lands, 109,992 acres now being under projects. The agricultural value of lands in the Reservations varies from worthless to the best in the State.

TRIBES AND THEIR CHARACTERISTICS

The Indians of Arizona mostly belong to three families, the Piman, Yuman, and Athapascan.

THE PIMAN FAMILY

The Piman family is represented in Arizona by two tribes, located in the southern and southeastern parts of the State, the Pima and Papago. Tradition indicates that the Hopis of the north central part of Arizona formerly belonged to this family, but their dialect is distinctly Shoshonean, and their family relationship is questionable. Their tribal customs and agricultural practices correspond quite closely to those of the Pimas and Papagoes, however, and their contribution to the science of dry-farming has been as great.

The Pima and Papago Tribes: Exploration of prehistoric ruins indicates that ancestors of the Pimas and Papagoes have been agricultural people for a great number of years. Corn, beans, wheat, chiles, and cotton have been their principal products; though they now purchase most of their cotton supply. Among the promising crop varieties secured from them are tepary beans and Papago sweet corn, both of which have been bred up and standardized by the Arizona Agricultural Experiment Station.

Pimas and Papagoes are particularly expert in the utilization of floodwaters for supplemental irrigation. Of late years they have

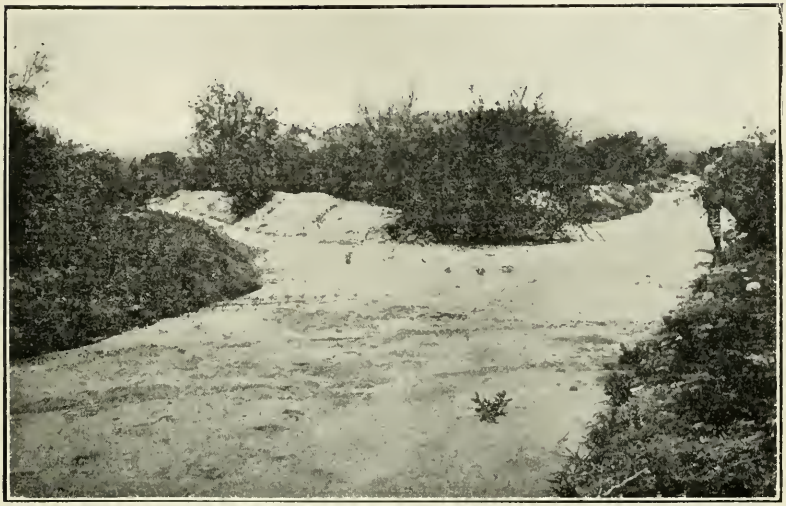

Fig. 10.—Papago floodwater, ditch west of Coyote Mountain, Pima County, Arizona.

Fig. 11.—Papago well, showing method of water raising.

devoted considerable attention to stock raising and have developed an interesting system of range management. In winter they move all their belongings into the mountains and higher valleys. Here they stay until well toward the end of the hot, dry spring and foresummer. Shortly before the usual summer rains are expected, they return to their homes at the lower elevations and plant their crops of corn and beans, bringing them to maturity by means of occasional irrigations with floodwater. After harvesting their summer crops they return to their homes in the mountains where the range, which has been refreshed by summer rains, furnishes a maximum amount of forage for their livestock. Thus they are able to guard against famine because of their wise range management and by taking immediate advantage of summer precipitation for dry-farming.

The Hopi Tribe: The Hopi Indians (sometimes called Moqui) like the Pimas and Papagoes are peaceful, though anything but cowardly. They are comparatively short in stature, stockily built, and possessed of great physical endurance, excelling in their long distance races. Usually they live in villages; while their fields are often several miles away. These Indians commonly make a run of ten or twelve miles to their fields, do a full day's work, and return home again in the evening without being much fatigued. Authentic reports indicate that occasionally they have run as far as one hundred miles in a day and at times they have been used to help catch wild horses, their efforts on foot being as valuable as those of white men on horseback in tiring wild range stock.

As far back as their history is known, the Hopis have been agricultural people. They are essentially religious and are divided into a number of clans, the chief ceremonies of each clan being centered about agricultural occupations. The interesting and well-known "Snake Dance," for example, is a ceremony of the Snake Clan, assisted by the Antelope Clan, for the purpose of winning the favor of the rain gods in order that summer rains may be ample to insure them good crops of corn and beans. This ceremony is held about the middle of the summer rainy season. The "Flute Dance" is a ceremony of the Flute Clan for the purpose of winning the favor of the gods controlling the supply of subterranean water which appears on the surface as springs.

The principal crops of the Hopis are corn and beans; and, like the Pimas and Papagoes, they have contributed several important

varieties for dry-farming, including Hopi Lima, White Hopi, and Bates' beans, and White Hopi and Blue Hopi corn.

The agricultural implements of dry-farming Indians are few. While a number of them have plows, many have none. Virtually all cultivation is done with hoes, and planting with a long hardwood dibber. Oftentimes the land farmed is covered with a thin veneer of sand which acts as a mulch and renders comparatively little cultivation necessary. At certain times of the year, often regardless of climatic conditions, they make their plantings, usually several inches deeper than varieties developed by white men will emerge from. In planting corn, the dibber is inserted twelve or fifteen inches deep and, as it is pulled out vertically, horizontal pressure is applied leaving a wedge shaped opening into which "a little boy's handful" or about twelve kernels are dropped. The seeds are covered loosely with soil, and the plants emerge with astonishing rapidity. The Indians have long since learned to properly space their plants, and rarely seed too thickly. Weeds are kept down by hand labor, and the farming is quite intensive.

When the season is especially dry and summer rains are delayed, seeds are often inserted in balls of moist clay, and the masses thrust into the dry earth. The moisture in these balls of clay is usually sufficient to germinate the seeds and supply the young plants until rain comes. An advantage of two or three weeks' additional growing season is thus secured.

Fruit growing is not practiced to a great extent among the Indians, though numerous peach orchards exist and oftentimes a fair quality of seedling fruit is produced. The trees grow in clumps and are never pruned or cultivated. The shifting of sand by wind oftentimes covers the tree trunks well up past the first forks of the limbs. Most of the orchards are planted in sandy and silt loams along washes and river bottoms where underground water exists near the surface. There are a few small irrigated orchards of apples, pears, and plums as well as peaches.

While the Piman family has contributed a number of very drought resistant varieties, natural selection must be given the credit. These Indians farm under extreme conditions, and destruction of the unfit through a long period of time has left only drought resistant strains. Since "seed is seed" with Indians, varieties are badly mixed: for instance, in a field of supposedly white corn, white,

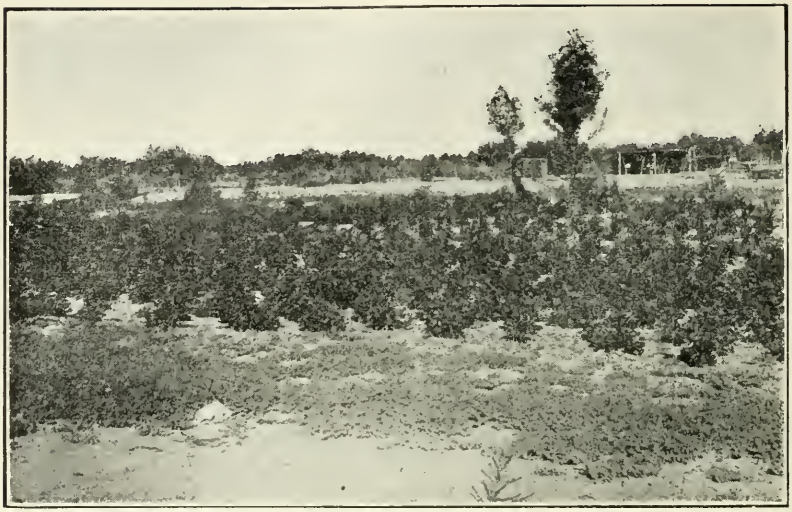

Fig. 12.—Chemehuevi Indian field on land subject to annual inundation by the Colorado River.

Fig. 13.—Yuma Indian field of corn and beans in a Colorado River slough after the annual flood.

dark blue, black, deep red, pink, yellow, and various combinations of the above may be found.

The modified characters of their corn varieties are interesting. Collins* reports that Indian varieties of corn emerged when the seed were planted at a depth of thirty-two centimeters, while the greatest depth through which Boone County White could penetrate was twenty centimeters. He found that the combined length of coleoptyle and mesocotyl of Indian corn was thirty-five and one-half centimeters, while that of Boone County White was but fifteen and four-tenths centimeters.

The thorough acclimatization of Indian varieties is further illustrated by the fact that tepary beans will form seed during the hottest part of the summer in the sub-tropical, irrigated valleys of Southern Arizona, while improved American varieties will fail unless flowering takes place in cooler weather, and oftentimes even their leaves will drop off.

THE YUMAN FAMILY

The Yuman family includes the Maricopa, Mohave, Yuma, and Hualpai tribes. The Chemehuevis, a Shoshonean tribe, from long association with the Yuman family have adopted the agricultural customs of the Yumas. This family has done little to promote dry-farming but has become expert in farming lands subject to periodic flooding by the Colorado River. As the water recedes crops are planted in the muddy ground, and the conservation and utilization of soil moisture is sufficiently thorough to insure maturity of the crops. Because of the irregular periodicity of the Colorado floods, the Yumas have not been able to insure against famine as completely as the dry-farming Indians of the Piman family.

THE ATHAPASCAN FAMILY

The strongest numerically and of least importance agriculturally is the Athapascan family, including the Navajo and Apache tribes. Their subsistence has come from the chase and raids upon stores of neighboring Indian tribes and white people.

In the early settlement of Arizona by Americans, some errors in management made the Apaches enemies constantly to be feared; and, while the Navajos have ordinarily remained at peace, there

*Jour. Agric. Research, Vol. 1, No. 4, Jan., 1914, p. 993.

has not existed the friendship that has been manifest between whites and the Piman family.

Agricultural practices of the Apaches and Navajos are mostly confined to stock husbandry, the Navajos, particularly, raising a considerable number of sheep. These sheep are descended from stock brought in by the early Spaniards, and their ancestry possibly includes both Karakul and North African blood. They are quite tall, but stockily built, and, though the dressing percentage is low, the carcass is of good quality. The color is far from uniform, and, because of a high proportion of hairs, prices for the wool average one-quarter to one-half lower than for wool from Merino range stock.

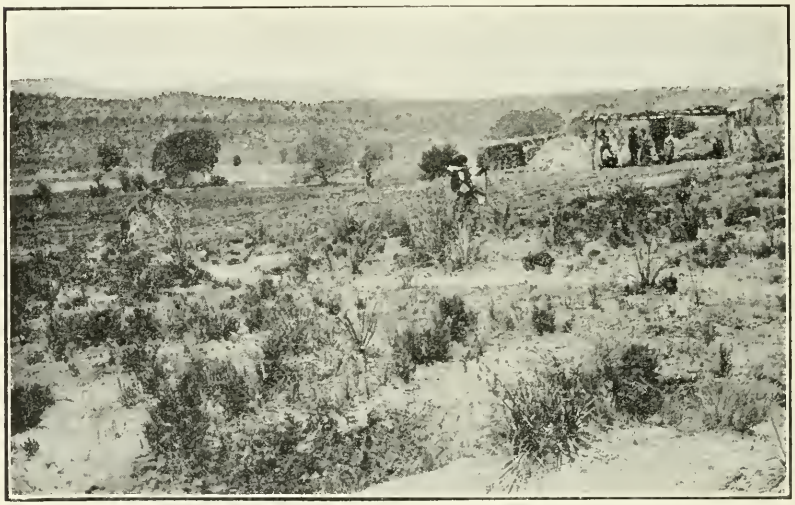

FIG. 14.—Apache village and farms, Northern Arizona.

In addition to sheep, goats, horses, turkeys, and some cattle are raised. The goats and cattle have recently been introduced, usually at the instigation of the United States Government. The horses are descended from original stock brought in by the early Spaniards, and, while very small, are quite tough and capable of considerable work both under the saddle and in the harness. Formerly large numbers of wild turkeys were found in various places in Arizona, and feathers from these birds have always been an important part

of ceremonial costumes. With the advance of civilization the wild turkeys were largely killed out, and, primarily to supply feathers rather than for any other purpose, the Indians recently have raised quite a number of domesticated turkeys.

HOME LIFE OF THE INDIANS

Tradition and old ceremonies are greatly cherished by the Indians and carefully taught to each rising generation. Usually, they have an abiding faith in the "Great Spirit," and, while the conception of the deity varies greatly with different tribes, they all are assured that he is watching over and helping them in their daily life. They often worship things of nature and utilize natural resources to the fullest extent.

Their home life is simple, and usually they are contented, honest, and true to their friends. The women build and own most of the homes. Within some tribes marriage is an important ceremony while in others men and women live together by common consent until they become dissatisfied, whereupon the "husband" moves his belongings, usually consisting of a horse, saddle, bridle, and blanket, to a new abode.

Ordinarily Indians do not care to take up the ways of white men, nor does it seem best that they should be forced to do so.

FARMING BY EARLY WHITE SETTLERS

Captain Weaver, a hunter and traveller along the Hassayampa River, cultivated a little garden patch about 1830, probably the first crop planted in Arizona by an American. His garden included melons, corn, and beans, the latter two being varieties which he secured from Indians.

Early settlers who engaged in farming on Sonoita Creek, a tributary of the Santa Cruz River, included E. G. Pennington, Tom Gardner, William Kirkland, Tom Hughes, and John Cady, who located in the order named between 1857 and 1872. These pioneers principally grew corn, beans, and wheat with the use of occasional floodwaters, after the example of Pima and Papago Indians.

In the fall of 1864, about seven years after the first attempts at farming on the Sonoita, Joseph Eagle and others put land in cultivation in Skull Valley, an old battleground of the Indians so named because of the large number of human skeletons found there. In

the spring of 1865 they planted corn, beans, and other garden vegetables, and in the succeeding fall harvested the first crops of produce raised without irrigation by Americans in Arizona.

About the same time other Americans settled in Williamson Valley, and a little later in Peeples' Valley. The main crop in these settlements was corn, the surplus being sold at Fort Whipple, near Prescott, for about twenty-five cents a pound.

In the Del Rio and Little Chino Valleys, land was put in cultivation in 1865 by George Bangheart and others. With irrigation these men produced mostly corn, root crops, garden vegetables, and potatoes.

The first farming by white men in the Verde Valley probably began in 1866, at the junction of Clear Creek and the Rio Verde. With irrigation the rich, alluvial soil produced good crops of corn. Considerable trouble with Indians was experienced in all of the earlier settlements, especially in the Verde Valley.

Because of reported possibilities for successful mining, the United States Government established a military post in 1863, at Del Rio, for the protection of prospectors against Indians. The following year this post was moved to Fort Whipple near Prescott. Most of the early settlers being interested in mining, only a few farmers persisted in following their vocation. High prices paid by miners and military authorities for farm produce, however, caused the establishment of a number of other ranches in Skull, Williamson, Peeples', and Verde Valleys as the mining population grew.

Attempts at dry-farming were made about 1870 in Navajo County, the early settlers following generally the example of Hopi Indians. In March, 1876, four colonies of Mormons arrived from Utah and settled on the Little Colorado River at Sunset, Brigham City, St. Joseph, and Obed. Their inability to cope successfully with the alkaline soil, and depredations by hostile Indians caused the settlements at Sunset, Brigham, and Obed to be abandoned. Most of the people removed to the vicinity of St. John, Woodruff, Snowflake, and Heber. They were able to produce good crops of corn, beans, and potatoes at Heber without irrigation, but at the other settlements irrigation has been practiced from the beginning. About three hundred acres were farmed at Heber for four years when the settlement was almost entirely abandoned because of depredations by Indians and white cattle "rustlers."

About this time Pinedale, Pinetop, Fort Apache, and Tuba City

were established. In 1875, William Mulligan located at Springerville where he cultivated about five hundred acres of land, his principal crop being barley, which was sold at Fort Apache for five cents a pound.

In Yuma County, M. M. Redondo began farming in Laguna Valley in 1871, cultivating about 1200 acres. His principal crop was alfalfa which was sold for about seventy-five dollars a ton. Considerable irrigating water was taken from the Colorado River.

At Quijotoa in Pinal County, farming, by means of supplemental irrigation with floodwaters, is said to have been commenced as early as 1883. Manuel Ramerez began to farm fifty acres in 1887, at Picacho, in Pinal County by methods similar to those of the Indians. His success soon attracted other farmers, and a permanent settlement was established.

Dry-farming began at Moccasin on the "Arizona Strip" in 1903 when Jonathan Heaton planted about fifteen acres of rye, which yielded about twelve and one-half bushels per acre. An additional five acres yielded fifty bushels of wheat.

While farming with floodwater was practiced at Fredonia as early as 1884, no strict dry-farming was engaged in until 1910, when the Brown brothers and Owen Judd located on White Sage Flat, where they have produced as high as twenty-five bushels of wheat per acre.

In 1881, Thomas McWilliam grew six to seven tons of potatoes per acre, selling them at twelve and one-half cents a pound. At the same time C. H. Shultz raised thirty bushels of corn per acre. A. H. Beasley grew good crops of potatoes and barley in 1884, selling his products at three and two cents per pound, respectively.

Little information is available about the earliest farming in Mohave County. In 1911, B. W. Hall planted eleven acres of wheat near Salome on the Parker cut-off. The wheat attained a height of four feet and yielded twelve tons of hay.

While a few cattle ranches were established in the early eighties in Sulphur Spring and the upper San Pedro Valleys, little dry-farming was attempted until 1907. Despite a number of successful attempts at dry-farming by the early settlers of Arizona, no great interest was shown until about 1910, and the ensuing four years mark the greatest advance of the industry, when fairly extensive developments occurred in various parts of the State.

EXPERIMENTAL WORK IN DRY-FARMING

In response to a need for data on dry-farming in Arizona, Experiment Station farms were established in 1908 at McNeal, in Sulphur Spring Valley; in 1909 at Snowflake, in the Little Colorado Basin; and in 1911 near Prescott, in Yavapai County. The land on the McNeal and Snowflake farms was leased, but title was secured to the Prescott Dry-farm. In 1913 the Sulphur Spring Valley Dry-farm, a mile south of Cochise, was purchased and, since conditions were similar, the Experiment Station Farm at McNeal was discontinued. The lease on the Snowflake Dry-farm was given up July, 1916, and to date no other Experiment Station farm has been established in the vicinity. Detailed data obtained on the Snowflake Dry-farm, the Prescott Dry-farm, and the Sulphur Spring Valley Dry-farm are given below, while Bulletin 70 of the Arizona Agricultural Experiment Station records the results obtained from operations on the McNeal Farm.

SNOWFLAKE DRY-FARM

Early in the fall of 1909, arrangements were made with Mr. W. J. Flake, Sr., of Snowflake, to use forty acres of his land, lying across Cottonwood Wash about one mile northwest of Snowflake, for experimental purposes. Part of this farm had been plowed several years before, but the sandy surface had been blown away and a fairly stiff clay subsoil exposed. The remainder of the farm was in sage brush. A layer of sand with a maximum depth of about seven inches covers much of the west thirty acres, and rocky spots occur frequently.

The shallow soil of the Flake farm rendered moisture conservation difficult, and in 1912 experimental work was discontinued and moved three miles up Cottonwood Wash to the farms of Mr. Don C. Smith and Mr. David Hancock where the soil was much deeper. The soil of the latter location is representative of a large area lying north of northeast of Holbrook and southeast of Woodruff. It is also typical of the valleys of 4500 to 5500 feet elevation lying between St. Johns and Snowflake.

Thirteen acres on the east end of the Flake farm were plowed and harrowed during September, 1909, following heavy rains. An additional seventeen acres were broken in January and February,

1910, following light rains. The field was then harrowed lightly. After rains during the succeeding March it was again harrowed and a good seed bed prepared.

The Smith property has been farmed intermittently since 1902. No effort had been made to control weeds for at least two years prior to the establishment of the Experiment Station farm. As a result, available soil moisture has been quite thoroughly exhausted, and persistent weeds seriously interfered with operations of the

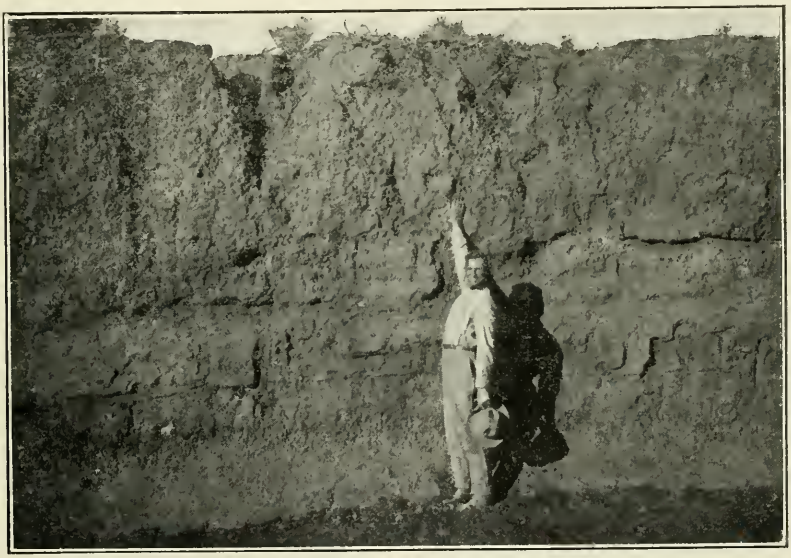

Fig. 15.—Wash on the Snowflake Dry-farm, showing uniformity of soil.

first two years. The soil, about ten feet deep, is a very fertile fine sandy loam veneered with four or five inches of wind-deposited sandy soil from Cottonwood Wash, the high winds of spring causing considerable soil movement. A part of the farm was plowed in the spring of 1912, and subsequently disced and cultivated with a knife weeder. The weeds persisted, however, and about one-half of the field was plowed shallow in July. A second and deeper plowing was made during late August and early September, but the weeds still persisted to send up sprouts until they were killed back by frost late in September. In order to expose underground stems of certain weeds to winter freezing, another plowing was started in December, but was unfinished because of a heavy freeze.

A portion of the farm was harrowed twice in April, 1913, and the remainder three times.

Five acres of the Hancock farm had been plowed in 1910, but the troublesome growth of weeds prevented preparation of a good seed bed for experimental cropping for more than a year. The remaining fifteen acres were cleared of scattered trees and brush in 1913. The Hancock farm lies on a low, gently sloping hill and has a soil varying from four to ten feet in depth. Tillage of this farm, preparatory to the first experimental planting, was similar to that of the Smith farm.

In the absence of reliable information, experiments on the Snowflake Dry-farm were planned in order to secure comparative data on crops and varieties best adapted, times of planting, rates of seeding, conservation and utilization of moisture, and economy of production.

BEANS

Table XX records the results of a variety test of beans for a six-year period ending in 1915.

Most of the varieties tested are well known. They include a number grown for an indefinite period by the Indians, and two local strains, Little's and Bates', which, in the absence of more suitable identification, are given the names of the gentlemen from whom they were secured.

Bean yields on the Flake farm were low in both 1910 and 1911. On the Hancock and Smith farms the highest yields in 1912 were only about 200 pounds per acre, and the beans were mostly destroyed by rabbits. High winds, drought and rabbits caused most varieties to fail in 1913, the only harvest being from plots of Bayou and Pink beans, and the largest yield was 116 pounds per acre. In 1914 effects of efforts directed against weeds began to be noticeable, and a more favorable season occurred with the result that yields of many varieties were high enough to insure some profit. The best showing was made by White and Red Hopi beans, while Colorado Pinto, a variety introduced in 1914, which has since been one of the best producers of the region, yielded 520 pounds per acre. In 1915, the entire crop was more satisfactory

TABLE XX. VARIETY TEST OF BEANS, SNOWFLAKE DRY-FARM

Variety	Field	Date planted	Stand	Date harvested	Size of plot	Yield per plot	Yield per acre
			%		*Acres*	*Pounds*	*Pounds*
1910							
Pink	Flake	5-13	85	10-15	½	25	50
White Tepary	"	5-15	50	....	1/6	6	36
Yellow "	"	5-14	50	10-19	1/6	7	42
Striped Bunch	"	5-14	35	10-15	½	40	80
1911							
White Tepary	"	4-21	50	10-10	¼	4	16
" "	"	4-25	..	10-22	¼	8	32
Yellow Tepary	"	4-21	..	....	..	....[1]	..
" "	"	6-8	..	....	¼	55	220
Pink	"	4-21	50	10-10	¼	9½	38
"	"	4-23	..	10-10	¼	51	204
"	"	6-8	..	....	¼	32	128
Striped Bunch	"	4-21	50	10-10	¼	33	132
Bates'	"	4-23	..	10-10	⅓	34	102
"	"	6-8	..	....	¼	61	244
1912							
Bates'	Hancock	5-24	60	9-24	¼	29	116
White Tepary	Smith	6-10	..	....	..	....[2]	...
" "	Hancock	5-24	..	....	..	....[2]	...
" "	Smith	7-20	..	....	..	....[2]	...
Yellow "	Hancock	5-29	..	....	..	....[2]	...
" "	Smith	6-10	..	....	..	....[2]	...
" "	"	7-20	..	....	..	....[2]	...
" "	Hancock	7-24	..	....	..	....[2]	...
Pink	"	5-24	50	9-24	¼	51[3]	204
"	Smith	6-10	..	9-23	¼	83	32
1913							
Bayou	Smith	6-14	..	9-30	¼	29	116
Pink	"	6-15	60	9-30	¼	21	84
"	"	6-16	..	....	..	....[1]	...
Bates'	"	6-17	..	....	..	....[1]	...
White Tepary	"	6-17	..	....	..	....[1]	...
" "	"	6-4	..	....	..	....[1]	...
1914							
Colorado Pinto	Hancock	7-7	90	10-10	¼	130	520
Valentine	Smith	6-24	60	10-10	¼	50	200
Pink	"	6-24	50	10-11	¼	120	480
Bayou	"	6-24	75	10-11	¼	132	528
Trammell	Hancock	6-24	75	10-15	¼	105	420
Little's	"	7-7	..	.....	¼	.....[4]	...
Lady Washington	Smith	4-28	60	9-19	¼	60	240
" "	"	6-24	90	10-5	¼	108	432
" "	Hancock	7-7	90	10-10	¼	60	240
White Tepary	"	6-26	..	.....	..	.....[5]	...
Bates'	Smith	6-4	60	10-4	¼	113	452
Hopi Lima	"	6-2	..	....	¼	.....[5]	...
Yellow Hopi	"	6-2	60	10-4	¼	100	400
White "	"	6-2	75	10-4	¼	180	720
Red "	"	6-2	70	10-4	¼	150	600
1915							
Lady Washington	Smith	5-3	75	10-9	¼	200	800
" "	"	5-26	75	10-9	¼	205	820
" "	"	6-19	75	10-9	¼	146	584
" "	Hancock	6-24	..	10-9	¼	60	240

1—Failed. 2—Destroyed by rabbits. 3—Injured by rabbits. 4—Immature. 5—Failed to mature.

TABLE XX.—*Continued*

Variety	Field	Date planted	Stand	Date harvested	Size of plot	Yield per plot	Yield per acre
1915—*Continued*			%		*Acres*	*Pounds*	*Pounds*
Little's	" ...	6-2	70	10-15	1/10	25	250
Colorado Pinto	Hancock	6-2	70	10-15	1/10	45	450
Red Hopi	" ...	6-2	60	10-15	¼	60	240
Valentine	" ...	6-2	65	10-15	¼	60	240
Bayou	" ...	6-2	70	10-15	¼	116	464
Pink	Smith ..	5-8	80	10-9	¼	150	600
Hopi Lima	" ...	5-19	50	.....	1/40	.....[5]	...
Casa Grande	" ...	5-19	65	10-20	1/40	20[5]	800
Aztec	" ...	5-20	75	10-20	1/80	.....[6]	...
Yellow Hopi	Hancock	5-28	50	10-15	¼	60	240
Black Tepary	" ...	5-21	80	10-1	¼	240	960
Yellow "	" ...	5-21	80	10-1	¼	280	1120
White "	" ...	5-21	85	10-1	¼	275	1100
White "	" ...	6-17	80	10-15	¼	125	500

5—Failed to mature. 6—Destroyed by thrips.

Fig. 16.—Dent corn and beans, Snowflake Dry-farm.

than in any previous year. The yield of about half of the varieties was sufficient to insure profit. Black, Yellow and White teparies

produced from 960 to 1120 pounds per acre. Yields from plots of Lady Washington beans were satisfactory and the desirability of Colorado Pintos and Bayous was again demonstrated. Hopi Limas, which have proven interesting on all of the Arizona Agricultural Experiment Station dry-farms, again failed to mature.

The variety test of beans is summarized in Table XXI. Annual yields of each variety are calculated as the average of yields of all plots of that variety. The adaptability of Teparies, Lady Washington, Colorado Pinto, and Bayou beans is shown.

TABLE XXI. SUMMARY OF VARIETY TEST OF BEANS, SNOWFLAKE DRY-FARM

Variety	Yield per acre						
	1910	1911	1912	1913	1914	1915	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	
White Tepary	36	24	...	...	...	800	143
Yellow "	42	110	...	...	...	1120	212
Black "	..	...	...	...	...	960	960
Lady Washington	..	...	...	...	304	611	457
Bates'	..	173	116	...	452	....	185
Pink	50	123	118	42	480	600	235
Colorado Pinto	..	...	...	...	520	450	485
Red Hopi	..	...	...	...	600	240	420
White Hopi	..	...	...	...	720	....	720
Hopi Lima	..	...	...	...	...	...	...[1]
Bayou	..	...	...	116	528	464	369
Valentine	..	...	...	...	200	240	220
Casa Grande	..	...	...	...	...	800	800
Striped Bunch	80	132	...	...	...	....	106
Trammell	..	...	...	...	420	...	420
Little's	..	...	...	...	...	250	125
Aztec	..	...	...	...	...	...	...[2]
Yellow Hopi	..	...	...	...	400	240	320

1—Failed to mature. 2—Blooms destroyed by thrips.

To determine the most favorable date on which to plant beans, a test which included the planting of one variety each year on various dates, was begun in 1912 and continued in 1914 and 1915. The Bates' variety was used in 1912, having been planted on dates ranging from May 24 to July 10. See Table XXII. The earliest planting was most successful, later plantings failing to mature. In 1914, Lady Washington beans were planted, the plot seeded June 24 yielding highest. Lady Washington beans were again used in 1915, plots seeded in May producing best results. From the data of Table XXII and from general observations it appears that beans in the Snowflake vicinity should be planted in May;

TABLE XXII. BEANS: TIME OF PLANTING TEST, SNOWFLAKE DRY-FARM

Variety	Date planted	Yield per acre	Remarks
		Pounds	
1912			
Bates	5–24	116	
"	5–25	48	Beans half matured
"	6–25	...	No beans matured
"	7–10	...	Pods just setting
1914			
Lady Washington	4–28	240	
" "	6–24	424	
" "	7–7	240	
1915			
Lady Washington	5–3	800	
" "	5–26	820	
" "	6–19	584	
" "	6–24	240	

June and July plantings being oftentimes too late to mature and April seedings usually too early.

It is obvious that because of the difference in the leaf area of bean varieties a corresponding difference in spacing the plants must be made. Experience indicates that rows of kidney beans and teparies should be not less than 36 inches apart, and that the distance between the plants in the row should be from twelve to eighteen inches. Planted in this manner, from six to nine pounds of seed per acre must be provided for such varieties as Pink, Bates', and Lady Washington, while, of the smaller varieties, such as Tepary and White Navy, from five to seven pounds are required.

Where soil moisture conditions are favorable it is desirable to plant beans with an ordinary planter. However, if a sub-surface crust appears in the soil or if soil moisture is low, planting in a lister furrow is to be preferred. Beans must be planted well into moist soil, if satisfactory germination is to be secured, the optimum depth being usually from three to six inchees.

Where precipitation is light and where moisture dissipating conditions are particularly effective, as in the Snowflake vicinity, very careful attention should be given to cultivation, which should be continued persistently until the flowers are setting and the plants have begun to spread to a considerable extent. Especially is it necessary that weeds be destroyed as quickly as possible after their appearance.

Several makes of bean hearvesters are sold by implement houses. A home-made harvester, however, consisting of a culti-

vator, with knives so placed that they will cut off the plants just beneath the surface of the ground, is very satisfactory. The vines should be cut and piled when they are toughened by dew, a hay rake often being satisfactory for bunching. Threshing may be done by a grain separator which has the speed of the cylinder much reduced and the concaves removed. Many beans are apt to be broken, but usually not enough to justify the trouble and expense of securing a regular bean separator.

Table XXIII is a financial statement of costs and returns from growing an acre of beans at the Snowflake Dry-farm in 1915. It will be noted that the yield per acre, 500 pounds, while not high, is sufficient to return a fair profit.

TABLE XXIII. RETURNS FROM AN ACRE OF BEANS, SNOWFLAKE DRY-FARM, 1915

Production costs per acre		Yield per acre	Gross returns per acre	Net gain
	Dollars	*Pounds*	*Dollars*	*Dollars*
Taxes	.75	...	....	....
Interest	.50	...	....	....
Plowing	2.00	...	....	....
One double disking	.50	...	....	....
Two harrowings	.30	...	....	....
Planting	.25	...	....	....
Four cultivations	.50	...	....	....
Hoeing	1.20	...	....	....
Harvesting	1.25	...	....	....
Seed	.50	...	....	....
Threshing	1.00	...	....	....
Total	8.75	500	20.00	11.25

CORN

Eight varieties of corn were planted in 1910 (see Table XXIV), and, as indicated by the table, most plots were replanted. No seed was produced, but the best yield was obtained from plots of Red Dent.

In 1911, seed was produced on most plots, the best yields being obtained from Yellow Dent and Australian White Flint. Four plots received an irrigation of floodwater.

In 1912, only Australian White Flint and Yellow Dent were grown, and the yields were small. One plot of Australian White Flint was destroyed because of soil movement by wind.

Nine varieties were grown in 1913, but, because of drought, no grain was produced except in a plot of Yellow Dent. The best yields were obtained from Hickory King, and a variety obtained from the Pima Indians.

In 1914, the season was much more favorable than in 1913, and a fair yield of ear corn was obtained from plots of White Flint, Blue Hopi, and Minnesota King. The best yield of forage was produced on a plot of Hickory King.

In 1915, 2133 pounds of ear corn per acre were produced on a small plot of White Hopi, and 2000 pounds of ear corn per acre on a plot of Australian White Flint. In general, yields were quite satisfactory and represent profitable returns from corn grown in the Snowflake vicinity for ensilage purposes.

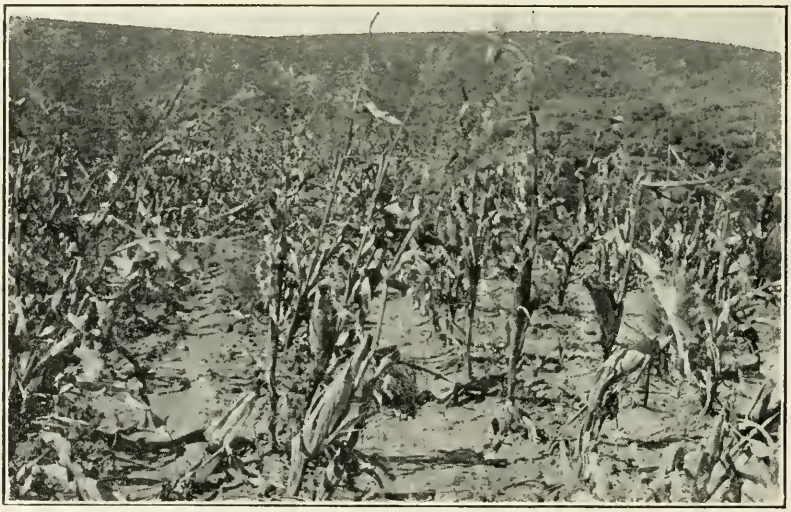

Fig. 17.—Corn, Snowflake Dry-farm, 1911.

Fig. 18.—White Dent corn, Snowflake Dry-farm, August 17, 1912.

Fig. 19.—Corn, Snowflake Dry-farm, June 22, 1915. Plot on left seeded May 10; plot on right seeded three weeks later.

TABLE XXIV. VARIETY TEST OF CORN, SNOWFLAKE DRY-FARM

Variety	Field	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
						Grain	Stover	Grain	Stover
1910			%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
White Flint	Flake	5–12 / 6–27	80	10–5	½	...	115	....	230
		..	.....	..	...	....[1]	....	....	
Cream Dent	"	5–13 / 6–29	50 / 65	10–5	½	...	120	....	240
		.....	..	...	....[1]	....	....		
Australian White Flint	"	5–13	..	10–2	½	...	200	....	400
Leaming	"	5–13 / 6–29	50 / ..	10–6	½	...	180	....	360
		.....	..	...	....[1]	....	....		
Iowa Silver Mine	"	5–14 / 6–29	50 / ..	10–11	½	...	200	....	400
		.....	..	...	....[1]	....	....		
Red Dent	"	5–14 / 6–27	75 / ..	10–12	½	...	503	....	1006
" "	"	.....	..	...	....[1]	....	....		
Etter's Red Dent	"	6–5	..	10–24	½	...	547[2]	....	1094
North Dakota Special	"	6–28	50	.....	⅓	...	332	....	996
		5–14 / 6–27	35 / ..	10–11	½	...	180	....	360
		.....	..	...	....[1]	....	....		
1911									
Australian White Flint	"	4–26	..	.....	¼	62	410[6]	248	1640
" " "	"	4–21	50	10–10	¼	15	114	60	456
" " "	"	6–17	..	10–10	¼	190	930	760	3720
White Flint	"	4–21	50	10–10	½	64	310	128	620
" "	"	6–17	..	10–10	¼	...	1230[3]	....	4920
" "	"	4–25	60	10–22	½	126	840[6]	252	1680
Hickory King	"	4–26	..	10–22	..	...	....	....	....
" "	"	4–21	50	10–10	½	...	296	....	592
Yellow Dent	"	4–21	..	10–10	¼	...	....[4]	....	....
" "	"	....	..	.....	1/6	61	200	366	1200
" "	"	4–26	60	10–22	¼	372	909[6]	1488	3636
Bloody Butcher	"	4–25	60	10–22	¼	...	1210[6]	....	4840
1912									
Australian White Flint	Smith	4–27	..	.....	..	...	....[5]	....	....
" " "	Hancock	5–20	60	10–14	¼	50	360	200	1440

1—Replanted. 2—Immature. 3—Fallow. 4—Failed. 5—Destroyed by wind. 6—Irrigated with floodwater.

TABLE XXIV.—*Continued*

Variety	Field	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
						Grain	Stover	Grain	Stover
1912—*Continued*			%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Yellow Dent	Smith	6–11	..	9–25	¼	...	160	....	640
" "	Hancock	5–20	..	10–14	¼	60	275	240	1100
1913									
Apache	Smith	6–16	75	10–1	¼	...	458	....	1832
White Flint	"	7–1	..	.....	1/20	...	46	....	920
" "	"	6–14	50	9–30	¼	...	147	....	588
Papago Sweet	"	6–7	..	10–2	¼	...	321	....	1284
Pima	"	6–11	..	10–2	⅛	...	296	....	2368
Hickory King	"	6–17	..	10–2	¼	...	715	....	2860
Bloody Butcher	"	6–14	..	10–2	¼	...	487	....	1948
Mexican Black	"	6–14	60	10–2	1/5	...	73	....	365
Mixed Hopi	"	6–14	40	9–30	¼	...	73	....	292
Yellow Dent	"	6–11	..	9–25	⅛	30	160	240	1280
1914									
Blue Hopi	Hancock	6–20	90	9–29	¼	360	1840	1440	7360
Minnesota King	Smith	6–24	75	9–27	¼	350	640	1400	2560
Pima	"	6–25	75	10–10	¼	...	900	....	3600
Apache	"	4–28	50	9–24	¼	170	300	680	1200
Hickory King	"	5–28	80	10–5	¼	...	2165	....	8660
Colorado Yellow Dent	"	7–8	95	10–5	¼	....[2]	797[7]	....	3188
White Flint	"	4–28	50	9–24	¼	360	650	1440	2600
1915									
Australian White Flint	Hancock	6–2	70	9–28	¼	500	900	2000	3600
Hickory King	Smith	5–8	75	9–28	1/10	...	495[7]	....	4950
White Flint	"	6–25	65	9–30	¼	...	1100	....	4400
White Hopi	"	5–20	90	9–28	3/40	160	540	2133	7200
Papago Sweet	"	6–17	75	9–30	7/40	...	536[7]	....	3061
Colorado Yellow Dent	"	5–8	80	9–30	4/40	...	631[7]	....	6310
Yellow Dent	"	5–3	80	9–14	3/40	60	150	800	2000
" "	"	5–26	80	9–14	3/40	56	140	747	1867
" "	"	6–19	60	9–21	3/40	28	90	373	1200

7—Calculated from green weight.

TABLE XXV. SUMMARY OF VARIETY TEST OF CORN, SNOWFLAKE DRY-FARM

Variety	Yield per acre (pounds)													
	1910		1911		1912		1913		1914		1915		Average	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
White Flint	....	230	127	2407	....	....	....	754	1440	2600	....	4400	313	2078
Cream Dent	....	240	....	....	....	....	....	....	....	....	....	....	....	240
Australian White Flint	....	400	356	1939	100	720	....	....	....	....	2000	3600	614	1665
Leaming	....	360	....	....	....	....	....	....	....	....	....	....	....	360
Iowa Silver Mine	....	400	....	....	....	....	....	....	....	....	....	....	....	400
Red Dent	....	1050	....	....	....	....	....	....	....	....	....	....	....	1050
Etter's Red Dent	....	996	....	....	....	....	....	....	....	....	....	....	....	995
North Dakota Special	....	360	....	....	....	....	....	....	....	....	....	....	....	360
Hickory King	....	....	....	296	....	....	....	2860	....	8660	....	4950	....	4192
Bloody Butcher	....	....	....	4840	....	....	....	1948	....	....	....	....	....	3394
Yellow Dent	....	....	618	1612	120	870	240	1280	....	....	640	1689	405	1363
Apache	....	....	....	....	....	....	....	1832	680	1200	....	....	340	1516
Papago Sweet	....	....	....	....	....	....	....	1284	....	....	....	3061	....	2172
Pima	....	....	....	....	....	....	....	2368	....	3600	....	....	....	2984
Mexican Black	....	....	....	....	....	....	....	365	....	....	....	....	....	365
Mixed Hopi	....	....	....	....	....	....	....	292	....	....	....	....	....	292
Blue "	....	....	....	....	....	....	....	....	1440	7360	....	....	1440	7360
Minnesota King	....	....	....	....	....	....	....	....	1400	2560	....	....	1400	2560
Colorado Yellow Dent	....	....	....	....	....	....	....	....	....	11600	....	6310	....	8955
White Hopi	....	....	....	....	....	....	....	....	....	....	2133	7200	2133	7200

As indicated in Table XXIV, early maturing and small growing corns are safest in the Snowflake vicinity. In the timber belt, where the rains are apt to be more plentiful, some of the larger improved American varieties may be successfully grown for silage, but best results will probably be obtained from the larger Indian varieties and the smaller and earlier eastern strains.

Table XXV summarizes the variety test of corn on the Snowflake Dry-farm. Annual yields represent the average of all plots of a given variety for the year specified.

To determine the optimum spacing of corn plants (see Table XXVI), six plots of White Flint were planted in 1913 in rows thirty-six inches apart and in hills from two to thirty-six inches apart. Because of the unfavorable condition of the season the data are not especially valuable.

TABLE XXVI. CORN; SPACING TEST, SNOWFLAKE DRY-FARM, 1913

Variety	Field	Size of plot	Distance between rows	Distance between hills	Fodder per plot	Fodder per acre
		Acres	*Inches*	*Inches*	*Pounds*	*Pounds*
White Flint....	Smith	1/20	36	2	46	902
" "	"	1/20	36	4	43	860
" "	"	1/20	36	6	38	760
" "	"	1/20	36	12	36	720
" "	"	1/20	36	24	25	500
" "	"	1/20	36	36	30	600

POTATOES

Potatoes were first grown on the Snowflake Dry-farm in 1910 (see Table XXVII), when one plot each of Early Ohio and Early Rose were planted. Both plots were so injured by shifting soil that it was necessary to replant June 29. The quality of the small yield, which was insufficient to replace the seed tubers planted, was inferior.

No potatoes were grown in 1911 or 1912, but in 1913 four varieties, all of which failed because of drought, were planted in the Smith field.

In 1914, five varieties, three standard and two local, were grown, the best results being obtained from Peachblow, the two local strains coming second and third, respectively. Yields in 1914 were sufficient to indicate that potato growing may be profitable.

TABLE XXVII. VARIETY TEST OF POTATOES, SNOWFAKE DRY-FARM

Variety	Field	Date planted	Stand	Date harvested	Size of plot	Yield per plot	Yield per acre
1910			%		*Acres*	*Pounds*	*Pounds*
Early Ohio	Flake	5-16	30	11-3	½	120[1]	240
Early Rose	"	5-16	30	11-3	½	70[1]	140
1913							
White Star	Smith	6-3	..	.....	3/40	....	.....
Early Ohio	"	6-4	..	.....	3/40	....	.....
Snowflake	"	6-6	..	.....	1/40	....	.....
Burbank	"	6-5	..	.....	3/40	....	.....
1914							
Early Ohio	"	5-20	80	10-25	¼	660	2640
Wrencher's Surprise	"	5-20	80	10-25	¼	1000	4000
Blue Victor	"	5-20	80	10-25	¼	550	2200
Snowflake	"	5-20	80	10-25	¼	1060	4240
Peachblow	"	5-20	85	10-25	¼	1400	5600
1915							
Vermont Gold Coin	"	5-13	80	11-13	3/40	800	10664
Mammoth Pearl	"	5-13	60	11-13	1/40	180	7200
Showlow	"	5-13	80	11-13	3/40	654	8720
Peachblow	"	5-13	30	11-13	1/40	176	7040
Lakeside	"	5-13	50	11-13	1/40	165	6600
Blue Victor	"	5-13	40	11-13	2/40	80	1600
Early Ohio	"	5-10	70	11-13	1/40	110	4400
" "	"	5-10	70	11-13	1/40	107	4280
" "	"	5-10	70	11-13	1/40	100	4000
" "	"	5-10	70	11-13	1/40	96	3840
" "	"	5-10	70	11-13	1/40	65	2600
" "	"	5-10	70	11-13	1/40	102	4080
" "	"	5-10	70	11-13	1/40	120	4800
" "	"	5-10	70	11-13	1/40	114	4560

1—Replanted June 29.

TABLE XXVIII. SUMMARY OF VARIETY TEST OF POTATOES, SNOWFLAKE DRY-FARM

Variety	Yield per acre				
	1910	1913	1914	1915	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Early Ohio	240	...	2640	4070	**1737**
Early Rose	140	...	....	.....	**140**
White Star	...	...	.....	.....	.....
Snowflake	...	...	4240	.....	**2120**
Burbank	...	...	.....	.....	.....
Wrencher's Surprise	...	...	4000	.....	**4000**
Blue Victor	...	...	2200	1600	**1900**
Peachblow	...	...	5600	7040	**6320**
Vermont Gold Coin	...	...	....	10664	**10564**
Mammoth Pearl	...	...	....	7200	**7200**
Showlow	...	...	....	8720	**8720**
Lakeside	...	...	....	6600	**6600**

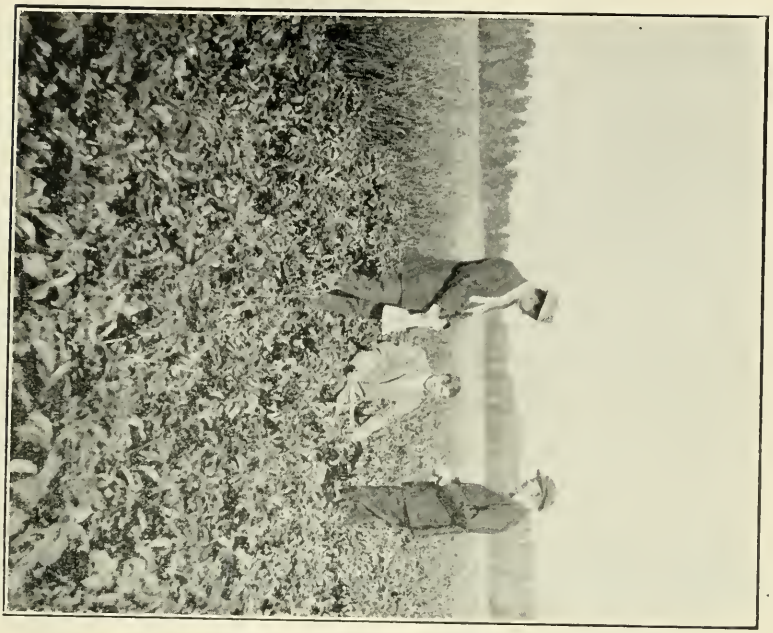

Fig. 20.—Potatoes and oats, Flagstaff, Arizona.

Fig. 21.—Potatoes and corn, Flagstaff, Arizona.

In 1915, seven varieties of potatoes were planted and profitable yields secured from most plots. A small plot of Vermont Gold Coin yielded over 10,000 pounds per acre.

Table XXVIII summarizes the variety test of potatoes on the Snowflake Dry-farm.

To determine the most profitable rate to plant potatoes an experiment was carried out in 1915, in which eight plots of early Ohio potatoes were planted at rates varying from 300 to 800 pounds of seed tubers per acre, with the resultant spacing of hills from eight to thirty-six inches apart in the row. The desirability of wide spacing is indicated by the yields (recorded in Table XXIX) which are greatest where planting is thin.

TALLE XXIX. POTATOES; RATE OF SEEDING TEST, SNOWFLAKE DRY-FARM, 1915

Variety	Seed tubers per acre	Distance between hills	Yield per acre
	Pounds	*Inches*	*Pounds*
Early Ohio.....	800	8	4000
" "	700	12	3840
" "	500	14	2600
" "	400	16	4080
" "	375	22	4800
" "	350	24	4560
" "	325	30	4400
" "	300	36	4280

Cultivation of potatoes is important, and, with each successive cultivation, soil should be gradually moved against the plant. Too much hilling exposes additional surface to moisture dissipating conditions, but slight ridging has a most beneficial effect upon the quality of tubers produced. In the early stages of growth, soils should be cultivated close to the rows, but, as the plants approach full size, close cultivation may interfere with the formation of tubers.

Climatic and soil conditions at the higher elevations of Arizona are oftentimes especially adapted to potato growing. The crop should be standardized, and one or two varieties selected and constantly improved.

Market conditions are usually favorable. The population of the mining camps and warmer portions of Arizona consumes more potatoes than are produced in the State at present. Because of high freight charges when potatoes are shipped in from other

states, prices are invariably high enough to insure good profits from any reasonable yield.

SMALL GRAINS

Wheat: One plot of Koffoid and two plots each of Turkey Red and Kubanka were planted in the fall of 1910, but failed to reach maturity. Other plantings, in the spring of 1913, failed because of drought. In the fall of 1914, three plots of Turkey Red and two of Marquis were planted on dates ranging from August 25 to November 15. The latest planting was winter killed but the remainder matured. It is interesting to note that biggest yields were produced from earliest seedings, and that yields consistently diminished with the lateness of planting. See Table XXX.

TABLE XXX. VARIETY TEST OF WHEAT, SNOWFLAKE DRY-FARM

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
					Grain	Straw	Grain	Straw
		%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1911								
Turkey Red....	9–12	..	....	½	...	...	....	....
" "	9–30	..	....	½	...	...	....	....
Koffoid	9–12	..	....	½	...	...	....	....
Kubanka	9–12	..	....	½	...	...	....	....
"	10–1	..	....	½	...	...	....	....
1915								
Turkey Red....	8–25	85	8–5	¼	480	588	1920	2352
" "	9–10	85	8–5	¼	300	385	1200	1540
" "	10–1	85	8–16	¼	217	297	868	1188
Marquis	10–15	70	8–24	¼	170	297	680	1188
"	11–15	..	....	..	...	...[1]	....	....

1—Winter killed.

Barley: One plot of barley planted in 1915 reached full size, but the grains were blasted by smut. See Table XXXI.

Emmer: In the fall of 1910, a plot of emmer was seeded, but failed to reach maturity. Black Winter Emmer, sown in the fall of 1914, yielded at the rate of 560 pounds of grain per acre.

Oats: Two plots of black oats, one from Utah and the other a strain grown locally for several years, were planted in the fall of 1914 and spring of 1915 respectively. The former was badly winter killed and yielded 128 pounds of grain per acre and 160 pounds of straw. The local variety, planted in spring, produced at the rate of 768 pounds of grain per acre.

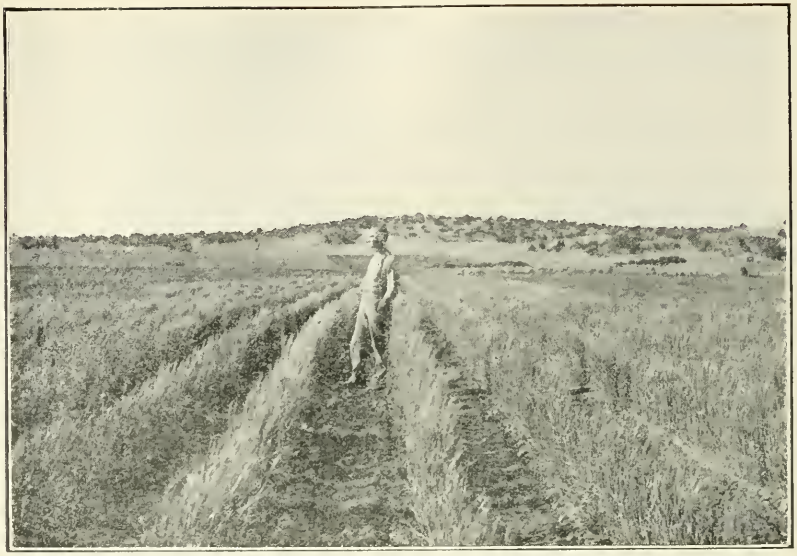

Fig. 22.—Turkey Red wheat, Snowflake Dry-farm, June 22, 1915.

Fig. 23.—Winter wheat, Snowflake Dry-farm, June 22, 1915. Plot on right seeded in September; plot on left seeded in November and winter killed

Fig. 24.—Spring wheat (left) and oats (right), Snowflake Dry-farm, June 22, 1915.

Fig. 25.—Spring planted oats, Snowflake Dry-farm, June 22, 1915.

TABLE XXXI. TEST OF BARLEY, EMMER, OATS AND RYE, SNOWFLAKE DRY-FARM

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
					Grain	Straw	Grain	Straw
		%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1911								
Emmer	9–13	..	.....	¼	...	..	...	..
1915								
White Hulless Barley	5–5	85	.....	..	...	..[1]	...	...
Black Winter Emmer	10–15	40	10–15	⅛	70	..	560	...
Black Winter Oats	12–1	10	9–1	⅛	16	20	128	160
Black (Snowflake) Oats...	4–26	80	8–16	¼	192	..	768	...
Spring Rye	5–5	90	9–1	1/10	90	..	900	...

1—Destroyed by smut.

TABLE XXXII. VARIETY TEST OF GRAIN SORGHUMS, SNOWFLAKE DRY-FARM

Variety	Field	Date planted	Stand	Date harvested	Size of plot	Fodder per plot	Fodder per acre
			%		*Acres*	*Pounds*	*Pounds*
1910							
Standard Milo..	Flake	5–12	70	10–5	½	250	500
" " ..	"	5–17	..	10–21	½	517	1034
White Kafir....	"	5–13	45	10–20	½	243	486
Broom corn....	"	5–13	50	10–11	½	590	1180
1911							
Standard Milo..	"	4–21	..	.....	½	....	....
" " ..	"	4–23	..	10–10	½	1230	2460
" " ..	"	4–25	..	10–1	¼	810	3240
Black-hulled White Kafir..	"	4–21	..	10–10	⅓	266	798
Black-hulled White Kafir..	"	4–23	..	.....	½	....	....
Black-hulled White Kafir..	"	7–25	..	10–1	¼	1240	4960
Broom corn.....	"	4–21	..	10–10	½	1460	2920
" "	"	4–23	..	10–10	½	2054	4108
" "	"	4–25	60	10–1	¼	116	464
1912							
Pink Kafir.....	Smith	6–10	..	9–25	¼	516	2064
" "	Hancock	5–20	..	10–14	¼	1205	4820
White Kafir....	Smith	6–10	..	9–26	¼	87	348
" "	Hancock	5–20	..	10–14	¼	640	2560
Dwarf Milo....	Smith	6–10	..	9–25	3/20	305	2033
" "	"	6–25	..	9–25	1/10	....[1]	....
" "	Hancock	5–22	..	9–21	¼	1190	4760
Standard Milo..	"	5–22	..	10–24	¼	910	3640
Broom corn.....	Smith	4–27	..	9–26	¼	1110	4440
" "	Hancock	5–22	..	10–14	¼	510	2040
Shallu	Smith	6–11	..	9–26	¼	170	680
"	Hancock	5–22	..	9–26	¼	436	1744
"	Smith	6–10	..	9–26	¼	273	1092

TABLE XXXII—*Continued*

Variety	Field	Date planted	Stand	Date harvested	Size of plot	Fodder per plot	Fodder per acre
			%		*Acres*	*Pounds*	*Pounds*
1913							
Feterita	Smith	6-14	..	.....	..	....[1]	....
Milo	"	6-14	..	.....	..	....[1]	....
White Kafir....	"	6-14	..	.....	..	....[1]	....
" "	"	6-14	..	.....	¼	73	292
Broom corn.....	"	6-2	..	.....	..	....[1]	....
" "	"	6-3	..	.....	..	....[1]	....
Black-hulled White Kafir..	"	6-3	..	.....	..	....[1]	....
Black-hulled White Kafir..	"	6-3	..	.....	..	....[1]	....
1914							
Feterita	Smith	6-1	60	10-15	¼	1660[2]	6640
Dwarf Milo.....	"	5-1	85	10-1	¼	1000	4000
1915							
White Kafir....	Smith	5-26	70	10-10	¼	2450	9800
Feterita	Hancock	6-17	5	.....	¼	....[1]	....
Shallu	"	6-7	75	10-10	¼	800	3200
Dwarf Milo....	Smith	5-3	95	9-27	3/40	415[3]	5533
" "	"	5-26	80	9-27	3/40	322[3]	4293
" "	"	6-19	75	9-27	3/40	275[3]	3666

1—Failed. 2—Immature. 3—Calculated from green weight.

Rye: A plot of spring rye, planted in the spring of 1915, produced at the rate of 900 pounds of grain per acre. It is likely that rye will become popular as a hay crop on dry-farms of the region.

SORGHUMS

Grain Sorghums: Three varieties of grain sorghums were planted in 1910 on the Flake farm (see Table XXXII), the best yield being produced by Broom Corn. Of the sorghums adapted for feeding, Standard Milo was most successful. In 1911, Broom corn again yielded highest, Black-hulled White Kafir second.

TABLE XXXIII. SUMMARY OF VARIETY TEST OF GRAIN SORGHUMS, SNOWFLAKE DRY-FARM

Variety	Yield of fodder per acre						
	1910	1911	1912	1913	1914	1915	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Standard Milo...	767	1900	3640	....	....	....	1577
White Kafir.....	486	....	1454	146	....	9800	2972
Broom corn.....	1180	2497	3240	....	....	....	1729
Black-hulled White Kafir....	....	1919	....	....	....	....	959
Pink Kafir.....	....	....	3442	....	....	....	3442
Dwarf Milo.....	....	....	2264	....	4000	4497	3587
Shallu	....	....	1172	....	....	3200	2186
Feterita	....	....	....	....	6640	....	2213

Several varieties were planted in 1912, the best yields being from Pink Kafir, Dwarf Milo, and Broom corn.

Because of drought all plots failed in 1913, and no crop was harvested except on plot of White Kafir which yielded less than 300 pounds of fodder per acre.

In 1914, the only grain sorghums grown were Feterita and Dwarf Milo, the latter producing 1600 pounds of seed per acre, the first sorghum seed produced on the Snowflake Dry-farm.

Best yields of the entire test were secured in 1915, a plot of White Kafir yielding 9800 pounds of dry fodder, while profitable results were obtained from Dwarf Milo and Shallu.

TABLE XXXIV. VARIETY TEST OF FORAGE SORGHUMS, SNOWFLAKE DRY-FARM

Variety	Field	Date planted	Stand	Date harvested	Size of plot	Fodder per plot	Fodder per acre
			%		*Acres*	*Pounds*	*Pounds*
1910							
Amber	Flake	5–13	65	10–5	½	460	920
1911							
Amber	Flake	4–21	50	10–10	½	924	1848
"	"	4–23	60	10–10	½	2010	4020
Sorghum	"	4–25	60	10–10	¼	810	3240
1912							
Amber	Smith	4–27	..	9–24	¼	456	1824
"	Hancock	5–20	..	10–14	¼	1115	4460
1913							
Sudan	Hancock	6–4	..	.....	..	....[1]	....
Sumac	Smith	6–3	..	.....	..	....[1]	....
Amber	"	6–14	..	.....	..	....[1]	....
"	"	6–14	..	.....	..	....[1]	....
"	"	6–14	..	.....	..	....[1]	....
"	"	7–12	..	.....	..	....[1]	....
"	"	7–17	..	.....	..	....[1]	....
1914							
Sudan grass....	Smith	7–6	80	10–20	¼	922[2]	3688
Amber	Hancock	5–26	5	.....	¼	....[3]	....
1915							
Amber	Smith	6–25	80	10–10	3/20	391[4]	2606
Red Top.....	Hancock	6–7	80	10–10	¼	1000	4000
Club Top.....	"	6–7	85	10–10	¼	750	3000
Sudan grass....	Smith	5–8	80	7–9) 9–20)	1/40	175	7000
" "	Hancock	6–2	80	7–9) 9–20)	1/40	95	3800
" "	Smith	5–8	80	10–15	1/40	5[5]	200
" "	Hancock	6–2	80	10–15	5/40	25[5]	200

1—Failed to germinate satisfactorily. 2—Immature. 3—Died from drouth. 4—Calculated from green weight. 5—Seed.

TABLE XXXV. SUMMARY OF VARIETY TEST OF FORAGE SORGHUMS, SNOWFLAKE DRY-FARM

Variety	Yield of fodder per acre						
	1910	1911	1912	1913	1914	1915	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Amber	920	2934	3142	....	....	2606	1600
Sorghums	....	3240	....	....	....	....	3240
Sumac	....	....	....	....	....	....	....
Sudan	....	....	....	....	3688	2800	2163
Red Top	....	....	....	....	....	4000	4000
Club Top	....	....	....	....	....	3000	3000

The variety tests of grain sorghums is summarized in Table XXXIII.

TABLE XXXVI. SORGHUMS; TIME OF PLANTING TEST, SNOWFLAKE DRY-FARM

Variety	Date planted	Yield per acre of fodder				
		1910	1911	1912	1913	1915
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Black-hulled White Kafir	4–21	....	798	....	....	....
" " "	4–23	....	....[1]	....	....	....
" " "	5–20	....	....	2560	....	....
" " "	5–25	2400	....	....	....	....
" " "	6–3	....	....	....	....[1]	....
" " "	6–10	....	....	348	....	....
" " "	6–14	....	....	....	292	....
Broom corn	4–25	....	464	....	....	....
" "	4–23	....	4108	....	....	....
" "	4–27	....	....	4440	....	....
" "	5–13	1180	....	....	....	....
" "	5–22	....	....	2040	....	....
" "	6–3	....	....	....	....[1]	....
Amber	4–21	....	1848	....	....	....
"	4–23	....	4020	....	....	....
"	4–27	....	....	1816	....	....
"	5–13	920	....	....	....	....
"	5–20	....	....	4460	....	....
"	6–14	....	....	....	....[1]	....
"	7–12	....	....	....	....[1]	....
"	7–17	....	....	....	....[1]	....
Milo	4–27	....	....	1660	....	....
"	5–6	....	....	2468	....	....
"	5–22	....	....	4760	....	....
"	5–25	....	....	940	....	....
"	6–5	....	....	780	....	....
"	6–10	....	....	2020	....	....
"	6–25	....	....	132	....	....
"	7–5	....	....	....[1]	....	....
"	5–3	....	....	....	....	5533[2]
"	5–26	....	....	....	....	4293[2]
"	6–19	....	....	....	....	3666[2]

1—Failed. 2—Calculated from green weight.

Forage Sorghums: A plot of Amber sorghum was planted in 1910, producing 920 pounds of dry fodder per acre. See Table XXXIV.

In 1911, two plots of Amber and a third of an unidentified sorghum were grown with fair success. One Amber plot yielded over 4000 pounds of dry fodder per acre.

The test in 1912 included two plots of Amber sorghum grown in the Smith and Hancock fields, respectively. The latter produced 4460 pounds of fodder per acre.

In 1913, all plots failed because of drought.

The test, in 1914, included Sudan grass and Amber. the latter dying from drought and the former yielding 3688 pounds of dry fodder per acre.

Amber, Red-top, Club-top, and Sudan grass were grown in 1915, best results being secured from Sudan grass, while fairly satisfactory returns were obtained from all plots.

Table XXXV is a summary of the forage sorghum test.

To indicate the optimum date to plant sorghums, a summary of results is shown in Table XXXVI which, in general, favors early planting.

The short frost-free season, combined with the relatively low temperatures of the Snowflake vicinity, is poorly adapted to the growing of sorghums. Seed is rarely produced and growth is not as rapid as it should be. However, profitable yields of ensilage material are often secured. Table XXXVII suggests proper rates of seeding.

TABLE XXXVII. SUGGESTED RATES OF SEEDING SORGHUMS
(Rows 36"-42" apart)

Grain sorghums		Forage sorghums	
	Pounds per Acre		*Pounds per Acre*
Milo	3–4	Sudan Grass	6–8
Kafir	3–4	" " (drilled)	10–15
Shallu	2–3	Amber	4–6
Kowliang	3–4	Sumac	4–6
Broom corn	2–3	Club Top	4–6
Feterita	3–4		

MISCELLANEOUS CROPS

Millet: There have been but two trials of millet on the Snowflake Dry-farm. In 1910, German millet was planted but failed, and in 1914, Kursk millet yielded 800 pounds of seed and 1000 pounds of straw per acre. See Table XXXVIII.

TABLE XXXVIII. VARIETY TEST OF MILLET, TEOSINTE, BROME GRASS, AND ALFALFA, SNOWFLAKE.DRY-FARM

Variety	Field	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
						Seed	Straw	Seed	Straw
			%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1910									
German millet	Flake	6–27	..	....	..	...	...[1]	...	....
1911									
Brome grass	"	....	..	....	..	...	...[2]	...	....
1912									
Teosinte	Smith	6–14	..	....	..	...	...[2]	...	....
1913									
Alfalfa									
Grimm	Hancock	5–28	..	....	..	...	...[3]	...	....
"	"	6–2	..	....	..	...	...[3]	...	....
Nebraska Dry Land	"	6–2	..	....	..	...	...[3]	...	....
Idaho Dry Land	"	6–2	..	....	..	...	...[3]	...	....
Montana Dry Land	"	6–2	..	....	..	...	...[3]	...	....
Turkestan	"	6–2	..	....	..	...	...[3]	...	....
1914									
Kursk millet	Smith	6–26	100	9–20	¼	200	250	800	1000
1915									
Alfalfa									
Turkestan	"	7–8	..	....	..	...	...	...	....
"	"	5–8	40	....	..	...	...[4]	...	....
Grimm	"	5–8	40	....	..	...	...[4]	...	....

1—Failed. 2—6 inches growth. 3—10 inches growth. 4—Destroyed by rabbits.

Alfalfa: Five varieties of alfalfa were planted in 1913 and grew to a height of ten inches. Three additional plots were seeded in 1915 but were destroyed by rabbits. It is not probable that alfalfa will be successfully grown in the vicinity without irrigation.

Bromus Inermis: Bromus Inermis (common brome grass) was planted in 1911, but grew to a height of only about six inches.

Teosinte: Teosinte, planted in 1912, made a growth of only six inches.

Fruit: No experimental work with fruit was carried out on the Snowflake Dry-farm. Orchards grown under similar conditions, however, indicate the desirability of a small orchard for home use. It is likely that such an orchard can be grown with little supplemental irrigation, even after the trees have come into full bearing.

FLOODWATER, SUMMER FALLOW, AND CONTINUOUS CROPPING

The only opportunity for comparison of continuous cropping, summer fallow and floodwater farming occurred in 1911. The Snowflake Dry-farm, as relocated, was not situated to catch floods.

TABLE XXXIX. COMPARISON OF FLOODWATER, SUMMER FALLOW, AND CONTINUOUS CROPPING, SNOWFLAKE DRY-FARM, 1911

Crop	Floodwater		Summer fallow		Continuous cropping	
	Yield per acre		Yield per acre		Yield per acre	
	Seed	Stover	Seed	Stover	Seed	Stover
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Sorghums						
Broom corn	....	460	....	4108	....	2920
Standard Milo	....	3240	....	2460	....	....
Amber	....	3240	....	4020	....	1848
Kafir	....	4960	....	2400	....	798
Average	....	**2975**	....	**3247**	....	**1392**
Corn						
White Flint	252	1640	440	2540	128	620
Australian White Flint	248	1640	380	1860	30	228
Yellow Dent	1488	3636	366	1200	....	....
Average	**663**	**2305**	**395**	**1866**	**53**	**.283**
Beans						
White Tepary	32	....	40	....	16	....
Pink	128	....	204	....	38	....
Striped Bunch	244	....	102	....	132	....
Average	**135**	....	**115**	....	**62**	....

Since the continuously cropped plots had only been in cultivation for two years, data obtained are not especially valuable. In Table XXXIX the results of supplemental irrigation by flooding, summer fallowing and continuous cropping are shown. The flooded land received but one overflow, which was quite heavy, in the early spring before crops were planted.

Moisture conditions of land continuously cropped, summer fallowed, and flooded are recorded in Table XL.

TABLE XL. MOISTURE DETERMINATIONS IN SOILS SUMMER FALLOWED, CONTINUOUSLY CROPPED, AND FLOODED, SNOWFLAKE DRY-FARM, 1911

Sample taken	Depth of sample	Continuously cropped			Summer fallowed		Flooded		
		Hole 1	Hole 2	Hole 3	Hole 4	Hole 5	Hole 6	Hole 7	Hole 8
		%	%	%	%	%	%	%	%
May 23	1st foot	8.15	8.16	8.80	11.05	14.81	12.25	12.33	18.03
" 23	2nd "	8.39	6.03	6.41	12.93	10.74	16.52	13.60	14.20
Aver'ge		8.27	7.09	7.60	11.99	12.77	14.38	12.96	16.12
Aug. 31	1st foot	6.94	...	8.43	7.63	9.47	9.21	15.45	10.10
" 31	2nd "	8.46	...	9.05	....	9.29	10.20	13.28	11.77
" 31	3rd "	...	...	9.70	....	8.65	12.19	14.73	.....
Aver'ge		7.70	....	9.06	7.63	9.14	10.53	14.49	10.93

Fig. 26.—Three-year-old dry-farm orchard, Pinedale, Arizona.

TABLE XLI. MOISTURE DETERMINATIONS, SNOWFLAKE DRY-FARM

Sample taken	Depth of sample	Hole 1	Hole 2	Hole 3	Hole 4	Hole 5	Hole 6	Hole 7*	Hole 8*
Flake Field		%	%	%	%	%	%	%	%
1910									
May 19	1st. foot	8.69	8.61	4.33	5.07	5.36	7.61	.....	.....
	2nd "	7.52	6.30	6.73	4.47	4.73	6.81	.....	.....
	3rd "	7.16	4.37	5.39	.....	.....	5.66	.....	.....
	4th "	....	....	4.54	....	.....	.....	.....	.....
	5th "	....	....	6.29	....	.....	.....	.....	.....
Average		7.79	6.43	5.45	4.77	5.04	6.69	.....	.....
Avg. all samples, 6.03									
Sept. 29	1st foot	5.98	8.40	5.42	4.11	7.42	.....	5.76	.....
	2nd "	....	6.61	4.50	3.80	4.26	.....	10.02	.....
	3rd "	9.08	6.80	3.80	.....	3.83	.....	7.50	.....
	4th "	6.22	....	4.12	.....	.....	.....	8.08	.....
Average		7.09	7.27	4.46	3.96	5.17	.....	7.84	.....
Avg. all samples, 5.96									
1911									
May 23	1st foot	8.15	8.16	8.80	11.05	14.81	12.25	12.33	18.03
	2nd "	8.39	6.03	6.41	12.93	10.74	16.52	13.60	14.20
	3rd "	....	....	3.47	.....	7.54	.....	.....	.....
Average		8.27	7.10	6.23	11.99	11.03	14.39	12.97	16.11
Avg. all samples, 11.01									
Aug. 31									
	1st foot	6.94	....	8.43	7.63	9.47	9.21	15.45	10.10
	2nd "	8.46	....	9.05	.....	9.29	10.20	13.28	11.77
	3rd "	....	....	9.70	.....	8.65	12.19	14.73	.....
Average		7.70	....	9.06	7.63	9.14	10.53	14.49	10.93
Avg. all samples, 9.93									
1912									
May 23	1st foot	8.41	15.10	13.30	14.27	12.18	9.12	10.33	.....
Smith and Hancock Fields	2nd "	13.11	18.10	16.41	11.23	13.02	15.41	16.21	.....
	3rd "	15.22	16.98	17.55	14.38	10.91	15.82	16.63	.....
	4th "	.....	.....	15.24	20.92	12.25	17.65	15.04	.....
	5th "	.....	.....	21.16	22.24	15.45	13.57	15.03	.....
	6th "	.....	.....	19.83	20.91	18.33	14.46	19.51	.....
	7th "	.....	.....	.....	.....	20.32	.....	.....	.....
	8th "	.....	.....	.....	.....	19.77	.....	.....	.....
	9th "	.....	.....	.....	.....	20.53	.....	.....	.....
Average		12.25	16.73	17.25	17.32	15.86	14.34	15.46	.....
Avg. all samples, 15.60									
1913	1st foot	10.30	8.60	.....	6.90	11.00	10.00	8.40	13.30
Aug. 1	2nd "	6.20	10.90	.....	12.30	12.90	12.70	9.60	17.60
	3rd "	7.30	11.50	.....	12.40	7.60	12.70	8.80	17.60
	4th "	5.00	10.10	.....	18.40	14.00	18.60	8.10	15.10
	5th "	.....	.....	.....	18.50	5.70	17.30	11.60	18.60
	6th "	.....	.....	.....	19.70	17.20	17.70	15.20	19.60
	7h "	.....	.....	.....	22.20	15.00	19.40	16.20	17.90
	8th "	.....	.....	.....	21.30	15.90	21.70	17.20	21.30
Average		7.20	10.27	.....	16.46	12.41	16.26	11.89	17.62
Avg. all samples, 13.16									

*From adjoining virgin land.

TABLE XLI—*Continued*

Sample taken	Depth of sample	Hole 1	Hole 2	Hole 3	Hole 4	Hole 5	Hole	Hole 7*	Hole 8*
		%	%	%	%	%	%	%	%
Dec. 12	1st foot	12.6	14.2	12.2	13.9	13.8	12.1	13.1	12.8
	2nd "	9.0	16.4	13.5	14.8	12.3	8.5	10.9	11.7
	3rd "	7.5	17.3	15.4	.....	11.0	11.5	9.0	15.0
	4th "	8.2	11.8	.....	13.9	13.8	14.9	12.0	16.3
	5th "	16.8	11.0	20.0	14.7	16.2	15.7	15.6	13.5
	6th "	21.9	13.5	18.4	20.3	17.9	16.3	11.7	11.9
	7th "	19.6	13.7	14.7	24.0	15.5	18.5	10.3	12.3
	8th "	17.6	12.9	17.3	.....	16.1	16.4	10.2	.....
Average		**14.1**	**13.8**	**15.9**	**16.9**	**14.6**	**14.2**	**11.7**	**13.4**
Avg. all samples, 14.3									
1914									
July 1	1st foot	3.7	6.2	4.4	4.5	7.5	8.5	6.8	6.6
	2nd "	6.6	14.8	13.9	12.7	11.8	12.7	16.0	10.8
	3rd "	8.6	11.7	.....	16.8	10.6	14.5	18.4	11.4
	4th "	6.5	8.2	18.3	16.7	18.6	16.4	17.3	13.7
	5th "	6.4	11.6	15.6	7.9	17.2	17.3	14.8	16.8
	6th "	10.0	16.5	19.6	15.9	18.0	19.4	....	19.0
	7th "	6.4	18.7	21.0	18.3	13.5	20.9	....	13.4
	8th "	....	21.3	21.0	16.4	15.8	21.4	....	11.0
Average		**6.0**	**13.6**	**16.3**	**13.6**	**14.1**	**16.4**	**14.6**	**12.8**
Avg. all samples, 13.4									
Oct. 20	1st foot	10.5	21.7	12.4	17.5	15.3	15.5	15.2	13.7
	2nd "	5.1	14.5	19.6	16.6	12.6	13.3	12.5	10.6
	3rd "	6.9	10.8	21.3	16.8	12.2	17.0	15.9	11.4
	4th "	6.2	8.5	18.0	15.6	19.0	19.5	14.3	11.0
	5th "	....	13.7	18.5	21.9	18.0	16.5	14.4	14.7
	6th "	....	19.0	23.3	18.2	17.7	21.2	14.7	14.3
	7th "	....	20.0	22.0	16.9	14.9	21.3	15.5	16.5
	8th "	....	19.7	22.6	15.8	16.0	23.3	19.2	....
Average		**7.2**	**16.0**	**19.7**	**17.4**	**15.7**	**18.4**	**15.2**	**13.2**
Avg. all samples, 15.3									
1915									
July 1	1st foot	6.4	8.9	5.7	5.4	7.9	12.1	11.3	9.4
	2nd "	7.8	15.5	8.7	17.6	12.2	14.2	15.0	12.9
	3rd "	11.6	17.5	20 0	8.2	15.2	18.1	15.0	14.5
	4th "	9.2	13.4	17.7	25.1	19.1	19.5	17.6	16.3
	5th "	....	17.1	17.4	10.7	18.5	19.6	13.6	20.0
	6th "	....	12.6	21.8	16.5	18.3	23.0	15.1	18.4
	7th "	....	13.5	21.2	17.5	17.4	24.7	16.2	20.2
	8th "	....	23.8	19.2	12 8	18.9	25.7	19.2	18.1
Average		**8.7**	**15.3**	**16.4**	**14.2**	**15.9**	**19.6**	**15.4**	**16.2**
Avg. all samples, 15.2									
Oct. 20	1st foot	5.6	9.9	11.6	10.9	10.6	12.6	7.2	5.6
	2nd "	6.5	15.6	11.35	11.0	10.8	13.4	13.6	8.2
	3rd "	9.4	13 6	18.9	13.9	12.3	18.8	....	9.1
	4th "	7.8	12.0	18.7	18.5	17.6	20.2	14.5	11.6
	5th "	...	15.8	15 1	17 0	17.5	19.2	13.7	18.1
	6th "	...	19.3	15.7	17.0	15.2	24 0	14.5	15.4
	7th "	...	20 3	18 1	21 6	17.4	25.3	16.3	19.4
	8th "	...	18 2	13.9	20.4	17 1	22.8	18.6	20.8
Average		**7.3**	**15.6**	**15.4**	**16.3**	**14.8**	**19.5**	**14.1**	**13.5**
Avg. all samples, 14.5									

*From adjoining virgin land.

MOISTURE STORAGE

To determine the variation in the moisture content of the soil, series of samples were analyzed in spring and fall each year the farm was operated. Borings were located at various representative places on the farm and eight-ounce soil samples were taken to a depth of eight feet where possible. The results are given in Table XLI. Samples in 1910 and 1911 were taken from the Flake field, and for the remainder of the period from the Smith and Hancock fields. The intention was at all times to take samples in summer immediately prior to the summer rains, and in fall when the land was driest.

A striking feature of the data in Table XLI is the low moisture content of the first foot of soil in late spring and early summer. Moisture dissipating forces are particularly active in spring and special care should be exercised to conserve all the moisture possible. A finely pulverized mulch in fall is undesirable, since it prevents ready percolation of water; while if the surface is rough, deeper penetration is secured, and a greater percentage of water remains in the ground. It has been observed that a surface crust forms in June even under mulches four to six inches deep. This crust is more pronounced in heavy soil but is evident in all types. The need of conserving sufficient moisture from winter precipitation to germinate and maintain seedings made prior to the formation of the sub-surface crust is manifest.

PRESCOTT DRY-FARM

In the summer of 1911, after several examination trips had been made over the promising agricultural districts of the vicinity, the Prescott Dry-farm was established seven miles north of Prescott and one and one-half miles north of P. & E. Junction, on the Santa Fe, Prescott & Phoenix Railroad.* The farm includes three soil types characteristic of the more important valleys of the region. It contains both level and steep lands, and affords opportunity for irrigation with diverted floodwater.

Establishment of the Prescott Dry-farm was made possible by cooperation of the Prescott Chamber of Commerce, through which business men of Prescott subscribed $2000; the Santa Fe, Prescott & Phoenix Railroad, which, through its general manager, Mr. W. A. Drake, subscribed $2000; and a $500 appropriation subscribed

*For map of Prescott Dry-farm see Twenty-eighth Ann. Rept. Ariz. Agric. Expt. Sta., p. 399.

through Governor R. E. Sloan of the Territory of Arizona. The operation of the farm since has been financed by appropriations from the State Legislature.

There were no dry-farms in the immediate vicinity, and the production of crops without irrigation was an untried experiment.

The southeast corner of the Prescott Dry-farm is the highest point on the place, being 5012 feet above sea-level, and the northwest corner, on Granite Creek, is the lowest, with an elevation of 4946 feet. The farm is cut diagonally into two nearly equal areas by a wash which originates in hills directly to the east. This wash is dry except in times of heavy storms when often it carries considerable water.

The higher parts of the farm were covered with a native growth of scrub oak. Other areas supported a fair growth of native grasses including white and blue grama, six weeks, buffalo, and bunch grasses. Approximately sixty acres are under cultivation. Knolls of the farm expose a red, compact loam which, when dry, is very hard and, when wet, very sticky. This soil contains a relatively large amount of fine clay particles. In places, this soil is mixed with coarse gravel. Soil of the grassy flats of intermediate elevation is darker colored and contains a high percentage of very fine sand particles. The bottom land is fertile, dark loam containing liberal amounts of organic matter and lying immediately adjacent to the creek. For mechanical and chemical analyses see Table X to XIII inclusive.

From its establishment until the present time, efforts on the Prescott Dry-farm have been mostly directed towards finding out the best adapted varieties of agricultural crops, the most practicable cultural operations, and a safe and reasonably dependable system of farm management.

ALFALFA

Three plots of alfalfa were planted in 1912 (see Table XLII), one of which was winter killed, one was destroyed by drought and rodents, and the third grew to a height of three inches before the cold weather of winter. Growth was renewed the following spring but the alfalfa was killed by drought in June, 1913. In 1913, twelve plots of Grimm, Peruvian, Algerian, Arabian, and Provence alfalfa were planted from seed produced by dry-farming in various localities

TABLE XLII. VARIETY TEST OF ALFALFA, PRESCOTT DRY FARM

Variety	Date planted	Size of plot	Remarks
1912			
Arizona Common.....	8–4		Killed by drought and rodents
Turkestan	8–4	1/6	Grew 3 inches until hit by frost, came out in spring and was killed by drought in June
Kansas			Winter killed
1913			
Montana Dry Land....	6–23	⅛	Growth of 6 inches
Nebraska " "	6–23	⅛	" " 6 "
Arabian No. 26461....	7–8	1/40	" " 6 "
Provence No. 24602...	7–8	1/40	" " 6 "
Peruvian No. 29353....	7–8		" " 6 "
Algerian No. 12846....	7–8		" " 6 "
Arizona Peruvian.....	7–8	1/40	" " 6 "
Turkestan	7–8	1/40	" " 6 "
Minnesota Grimm.....	7–8	1/40	" "12 "
Arizona Common.....	7–8	1/40	" " 6 "
Northern	7–8	1/40	" " 6 "
Idaho Dry Land	7–8	⅛	" " 6 "
1914			Growth of 6 to 8 inches
1915			Growth of 6 to 8 inches
1916			Plowed under

Fig. 27.—Beans, Prescott Dry-farm.

TABLE XLIII. VARIETY TEST OF BEANS, PRESCOTT DRY-FARM

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot	per acre Yield
1912		%		*Acres*	*Pounds*	*Pounds*
Tepary	5-16	90	10-8	¼	213	852
"	7-20	85	10-10	⅛	12	96
"	8-4	..	.....	¼	...[1]	...
"	5-28	..	.....	¼	...[2]	...
Lima	5-28	..	.....	..	...[1]	...
Bates'	5-20	..	9-6	¼	177	708
"	6-5	80	10-7	¼	194	776
Lady Washington	6-10	50	10-8	¼	100	400
" "	7-20	70	9-18	⅛	18	144
" "	5-10	85	9-18	¼	70	280
Pink	6-6	25	10-4	1/5	21	105
Wax	5-22	..	.....	..	...	...
1913						
Bates'	5-21	90	8-12	1/40	19	760
"	5-13	60	8-12	⅛	26½	212
Colorado Pinto	5-13	60	8-12	⅛	23	184
Lady Washington	5-13	50	8-12	⅛	23	184
Little's	6-2	20	10-20	⅛	10	80
Aztec	5-26	70	.....	..	...[3]	...
Lima	5-21	..	.....	..	...[4]	...
Tepary	5-21	..	.....	..	...[4]	...
Black Wax	5-13	10	10-9	⅛	⅛	1
Indian Yellow	5-13	20	10-9	⅛	6	48
Burpee's Stringless	5-22	10	10-18	¼	¼	1
" "	5-13	20	8-12	⅛	1¼	10
" "	5-26	..	.....	..	...[4]	...
Pink	5-13	75	10-9	⅛	25	200
Bayou	5-13	75	10-9	⅛	14	112
1914						
Red Hopi	6-5	90	10-5	1/16	3	48
White Hopi	6-5	90	10-5	1/40	3	120
Yellow Hppi	6-5	90	10-5	1/40	10	400
Hopi Lima	6-5	90	10-5	1/80	3	240
Colorado Pinto	5-12	90	9-27	¼	41	164
" "	5-13	80	9-12	¼	46	184
Tepary	5-12	90	10-1	1/16	9	144
"	5-14	90	10-2	1/16	37	592
Black Wax	5-12	40	10-1	1/40	2	80
Spotted Stringless	5-12	30	10-1	1/40	1½	60
Burpee's Stringless	5-12	30	10-1	1/16	4	64
Lady Washington	5-14	90	10-2	1/16	55	880
" "	5-14	80	9-17	¼	25	100
Bates'	5-14	50	9-17	1/5	36	180
"	5-14	90	10-2	1/16	24	384
Hanson	5-12	70	9-30	¼	27	108
Bayou	5-13	90	9-30	¼	60	240
Pink	5-14	95	9-17	¼	4	16
"	5-14	90	10-2	1/16	14	224
Casa Grande	6-5	90	10-5	1/16	10	160
Yellow Casa Grande	6-5	90	10-5	1/20	8	160
Little's	5-12	35	9-21	¼	7	28

1—Immature. 2—Destroyed by prairie dogs. 3—Destroyed by fungus disease. 4—Destroyed by rabbits.

TABLE XLIII.—*Continued*

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot	Yield per acre
		%		*Acres*	*Pounds*	*Pounds*
1915						
Tepary	5–18	85	10–4	¼	180	720
Little's	5–18	65	10–4	⅛	31	248
Yellow Hopi	5–18	85	10–4	⅛	53	424
White Hopi	5–18	80	10–4	⅛	42	336
Casa Grande	5–18	80	10–4	⅛	27	216
Hanson	5–18	95	10–4	⅛	64	512
Valentine	5–18	70	9–21	1/10	7	70
Pink	5–19	95	11–2	1/10	4	40
Bates'	5–19	90	10–4	¼	194	776
Colorado Pinto	5–19	90	10–4	¼	203	812
Heward Pinto	5–19	75	10–4	1/10	17	170
Red Hopi	5–19	85	10–4	⅛	24	192
Lady Washington	5–10	80	11–2	1/12	62	744
Bayou	5–19	85	11–2	¼	131	524

of the United States. The plot of Minnesota Grimm made the best growth, attaining a height of twelve inches during the summer. The remainder of the plots grew about one-half as tall. A growth of six or eight inches was made in both 1914 and 1915, and in 1916 all the alfalfa was plowed under.

BEANS

Beans are of special importance to Arizona dry-farmers. As legumes they have great value in crop rotations, and, since there are a number of varieties which have been thoroughly acclimatized throughout a long period of time by the native Indians, no surer crop can be grown on Arizona dry-farms.

Six varieties were planted on the Prescott Dry-farm in 1912. See Table XLIII. Best results were obtained from Bates' and tepary beans.

In 1913 six other varieties were added, the plot of teparies being destroyed by rabbits, and the Bates' variety maintaining its satisfactory yield of the year before.

The highest yielding variety of beans in 1914 was Lady Washington, with teparies producing satisfactorily.

In 1915 the leading varieties were Colorado Pinto, Bates', Lady Washington, and tepary .

Table XLIV summarizes the average yields of all plots of each variety for the four years of the test, the desirability and consistent

TABLE XLIV. SUMMARY, VARIETY TEST OF BEANS, PRESCOTT DRY-FARM

Variety	Yield per acre				
	1912	1913	1914	1915	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Tepary	237	...[1]	368	720	331
Bates'	742	486	282	776	571
Lady Washington	275	184	490	744	423
Pink	105	200	120	40	116
Bayou	...	112	240	524	292
Lima	...[2]	...[2]	...	...	...
Colorado Pinto	...	184	174	812	390
Little's	...	80	28	248	119
Burpee's Stringless	...	4	64	...	34
Black Wax	...[3]	1	80	...	40
Indian Yellow	...	48	...	...	48
Aztec	...	...[4]	...	...	...
Red Hopi	...	...	48	192	120
Hanson	...	...	108	512	310
White Hopi	...	...	120	336	228
Yellow Hopi	...	...	400	424	412
Casa Grande	...	...	160	216	188
Hopi Lima	...	...	240	...	240
Valentine	...	...	...	70	70
Howard Pinto	...	...	...	170	170
Spotted Stringless	...	...	60	...	60
Yellow Casa Grande	...	...	160	...	160

1—Destroyed by rabbits. 2—Immature. 3—Destroyed by prairie dogs. 4—Destroyed by fungus disease.

performance of Bates', Lady Washington, and tepary beans being shown.

To determine the most favorable date to plant beans, several

TABLE XLV. BEANS; TIME OF PLANTING TEST, PRESCOTT DRY-FARM

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot	Yield per acre
		%		*Acres*	*Pounds*	*Pounds*
1913						
Lady Washington	5–10	..	9–18	¼	70	280
" "	6–10	80	10–18	¼	100	400
" "	6–20	70	9–18	⅛	18	144
Tepary	5–16	90	10–8	¼	213	852
"	6–20	85	10–10	⅛	24	192
"	8–4	..	.....	....	...[1]	...
1914						
Lady Washington	4–10	..	.....	....	...[2]	...
" "	5–4	60	9–26	1/12	12	144
" "	5–10	70	9–26	1/12	13	156
" "	6–10	60	9–26	1/12	17	204
1915						
Lady Washington	5–19	85	11–2	¼	131	524
" "	5–10	80	11–2	1/12	62	744
" "	6–10	50	11–2	1/40	6	240

1—Did not mature. 2—Froze down.

plots were seeded on various dates in 1913, 1914, and 1915. Lady Washington beans were used throughout the test, and teparies were added in 1913. The data are somewhat incomplete, though the results, supplemented by additional experience, indicate the desirability of May planting. See Table XLV.

Of special interest is the tepary bean, which has been bred up from parent stock secured from the Papago Indians, therefore well adapted to climatic conditions of Arizona. No variety that has been tried on any of the Experiment Station farms seems so well adapted. Tepary beans now on the market are white, though the parent stock included many colors. Interest is developing throughout the entire United States, and the demand is constantly increasing. When properly cooked, tepary beans have a delightful flavor, being preferred by many to other varieties. The cooking methods which are ordinarily used for other varieties of beans must be somewhat modified to obtain best results from teparies. They mature quickly, and, under favorable conditions, yield a very large tonnage for green manuring purposes or for hay. Teparies must be protected from rabbits.

Another very promising variety of beans is Bates'. It is equal

Fig. 28.—Papago Sweet corn, Prescott Dry-farm.

TABLE XLVI. VARIETY TEST OF NATIVE INDIAN CORN, PRESCOTT DRY-FARM

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
					Grain	Stover	Grain	Stover
		%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1912								
Yellow Hopi....	5–10	..	9–6	¼	221	221	884	884
" "	5–20	..	10–7	¼	165	232	660	928
" "	6–3	..	10–12	⅛	200	381	1600	3048
" "	6–3	..	10–12	⅛	169	341	1352	2728
Pima	5–16	..	9–26	¼	200	693	800	2772
Papago Sweet..	5–15	..	10–5	1/20	87	243	1740	4860
1913								
Yellow Hopi....	5–26	..	10–13	⅛	92	138	736	1104
Hopi White Flint	5–15	60	10–15	⅛	172	389	1376	3112
Blue Hopi.....	5–14	60	10–15	⅛	200	300	1600	2400
White Hopi....	5–14	60	10–15	⅛	26	49	208	392
Pima	5–15	..	10–15	¼	271	544	1084	2176
Papago Sweet..	5–14	..	10–15	1/20	41	83	820	1660
1914								
Papago Sweet..	5–12	95	9–25	1/12	41	361	492	4332
White Hopi....	5–14	85	9–9	1/12	62	95	744	1140
" "	5–13	80	9–10	1/80	9	36	720	2880
Yellow Hopi...	5–14	85	9–9	1/12	25	94	300	1128
" " ...	5–13	80	9–16	1/80	8	14	640	1120
Pink " ...	5–14	75	9–14	1/40	9	30	360	1200
Red " ...	5–13	80	9–10	1/40	21	26	840	1040
" " ...	5–13	85	9–16	1–80	13	48	1040	3840
Pinto	5–13	80	9–16	1/40	14	40	560	1600
Delicious Hopi	5–13	70	9–10	1/40	20	35	800	1400
Blue Hopi.....	5–13	90	10–3	1/40	15	75	600	3000
" "	5–13	95	10–3	1/6	48	599	288	3594
Hopi Squaw...	5–13	70	9–10	1/40	14	23	560	920
Mixed Hopi...	5–13	80	9–10	1/40	26	38	1040	1520
Palakai	5–13	90	9–16	1/20	25	130	500	2600
Koescha Kai ...	5–13	90	9–16	1/80	20	23	1600	1840
Heroosquapa ..	5–13	90	9–16	1/40	15	33	600	1320
Pima	5–13	90	9–16	1/40	55	71	2200	2840
"	7–10	90	9–25	⅛	...	465	....	3720
"	5–13	100	10–1	¼	84	621	336	2484
Mohave	5–13	90	10–3	1/40	31	128	1240	5120
White Flint....	5–13	90	10–3	1/40	25	71	1000	2840
1915								
Papago Sweet..	5–18	100	10–10	⅛	21	500	168	4000
" " ...	5–19	95	10–21	⅛	...	...	....	....
Yellow Hopi...	5–18	95	10–10	⅛	98	15	784	1256
Red " ...	5–18	95	10–10	⅛	44	165	352	1320
Mixed " ...	5–18	95	10–10	1/20	37	101	740	2020
Blue " ...	5–17	95	10–6	⅛	99	134	792	1072
White " ...	5–18	95	10–9	⅛	143	200	1144	1600
Hopi Squaw....	5–18	95	10–10	⅛	103	98	824	784
Pima	5–18	40	10–11	1/40	19	80	760	3200
"	5–18	95	10–9	⅛	154	249	1232	1992
White Flint....	5–18	95	10–10	1/12	126	596	1512	7152

in quality to any kidney beans, and is particularly adapted to the climate of many regions in Northern Arizona.*

In 1914, a fungus disease appeared, the greatest damage being done to pink beans.

CORN

Native Indian Varieties: For convenience in comparison, tables recording variety tests of corn are divided into two groups, native Indian, and improved American varieties. The origin of Indian varieties is not known further than that they have been grown for a great many years by various tribes in the State. Some have distinct varietal characteristics, while others should be considered merely as races. In Tables XLVI and XLVII Papago sweet is included among Indian varieties, though it has been bred up and adapted until it may well be considered an improved American variety.

Three varieties of native corn, Yellow Hopi, Pima and Papago sweet, were planted in 1912. The best yield, 1740 pounds of ear corn per acre, was obtained from the plot of Papago sweet. Two plots of Yellow Hopi yielded 1352 and 1600 pounds of ear corn per acre, respectively. See Table XLVI.

Supplementing varieties grown in 1912, Hopi White Flint, Blue Hopi, and White Hopi were added to the test in 1913. The best yield was obtained from Blue Hopi.

In 1914, Mohave, several additional strains of Hopi, and three varieties, Palakai, Koescha Kai and Heroosquapa, obtained from Toriva, were added. The maximum yield of 2200 pounds of ear corn per acre was secured from a plot of Pima.

Fewer varieties were planted in 1915, the best yield being obtained from a plot of White Flint.

In Table XLVII, which summarizes the variety test of native Indian corn, annual yields represent the average of all plots of the specified variety for the given year.

The desirability of certain Indian varieties of corn for dry-farming is clearly evident. A degree of drought resistance has been bred up by natural selection for an unknown period of years,

*For a description of bean varieties see Arizona Agricultural Experiment Station Bulletin No. 68, "Southwestern Beans and Teparies," by George F. Freeman.

TABLE XLVII. SUMMARY, VARIETY TEST OF NATIVE INDIAN CORN, PRESCOTT DRY-FARM

Variety	Yields per acre									
	1912		1913		1914		1915		Average	
	Corn	Stover	Corn	Stover	Corn	Stover	Corn	Stover	Corn	Stover
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Papago Sweet	1740	4860	820	1660	492	4332	84	2000	784	3213
Pima	800	2772	1084	2176	845	3015	996	2596	931	2640
Yellow Hopi	1124	2397	736	1104	470	1124	784	1256	778	1470
Blue "	....	....	1600	2400	444	3297	792	1072	945	2256
White "	....	....	208	392	732	2010	1144	1600	695	1334
Mixed "	....	....	....	....	1040	1520	740	2020	890	1770
Red "	....	....	....	....	940	2440	352	1320	646	1880
Pink "	....	....	....	....	360	1200	....	....	360	1200
Delicious Hopi	....	....	....	....	800	1400	....	....	800	1400
Hopi White Flint	....	....	1376	3112	....	....	....	....	1376	3112
Hopi Squaw	....	....	....	....	560	920	824	784	692	852
Pinto Hopi	....	....	....	....	560	1600	....	....	560	1600
White Flint	....	....	....	....	1000	2840	1512	7152	1256	4996
Palakai	....	....	....	....	500	2600	....	....	500	2600
Heroosquapa	....	....	....	....	600	1320	....	....	600	1320
Koescha Kai	....	....	....	....	1600	1840	....	....	1600	1840
Mohave	....	....	....	....	1240	5120	....	....	1240	5120

TABLE XLVIII. VARIETY TEST OF IMPROVED AMERICAN CORN, PRESCOTT DRY-FARM

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
					Grain	Stover	Grain	Stover
1912		%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
White Dent	5–16	..	9–19	¼	213	857	852	3428
" "	5–28	80	10–12	¼	400	1019	1600	4076
Reid's Yellow Dent	5–24	..	10–12	⅛	100	315	800	2520
Reid's Yellow Dent	5–22	..	10–7	¼	412	865	1648	3460
Rice Pop	5–20	..	10–7	1/20	15	125	300	2500
Mexican Black	5–22	..	10–12	¼	19	349	76	1396
Sweet	5–20	..	10–7	1/20	27	375	540	7500
1913								
Brown County Yellow Dent	6–10	60	10–13	⅛	121	204	968	1632
Brown County Yellow Dent	6–10	60	10–8	⅛	51	51	408	408
Strawberry	6–10	60	10–13	⅛	218	327	1744	2616
"	6–10	60	10–8	⅛	178	267	1424	2136
Mexican Black	5–23	60	10–14	¼	83	166	332	664
Bloody Butcher	5–15	60	10–15	¼	416	789	1664	3156
" "	5–15	60	10–15	1/10	210	285	2100	2850
Sixty Day.....	5–15	60	10–15	¼	78	234	312	936
King Philip....	5–15	60	10–15	1/10	234	540	2340	5400
White Dent....	5–15	60	10–15	⅛	200	335	1600	2680
" "	5–15	60	10–15	1/10	121	484	1210	4840
Red "	5–14	60	10–15	⅛	125	260	1000	2080
Maul's Yellow Dent	5–14	60	10–15	⅛	46	93	368	744
Elgin Yellow Dent	5–14	60	10–15	⅛	41	83	328	664
Reid's Yellow Dent	5–21	..	10–18	⅛	490	739	3920	5912
Hickory King..	5–21	..	10–13	¼	363	1180	1452	4720
Sweet	5–23	..	10–14	1/10	317	317	3170	3170
1914								
Colorado Yellow Dent	5–12	95	9–27	¼	225	656	900	2624
Colorado White Flint	5–12	80	9–16	⅛	35	221	280	1768
King Philip....	5–13	95	9–27	1/12	25	208	300	2496
Swadley	5–13	95	8–5	¼	275	336	1100	1344
White Dent....	5–13	95	10–1	¼	18	1144	72	4576
" "	5–14	90	10–12	1/6	605	1266	3630	7596
" "	6–5	60	9–19	¼	...	772	....	3088
Reid's Yellow Dent	5–13	90	9–27	¼	110	1463	440	5852
Reid's Yellow Dent	5–14	..	10–12	3/20	199	628[1]	1326	4187
Maul's Yellow Dent	5–13	95	9–28	⅛	206	414	1648	3312
Maul's Yellow Dent	5–14	90	9–15	1/12	67	360	804	4320

1—Calculated from green weight. 2—Failed to come up.

TABLE XLVIII—*Continued*

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
					Grain	Stover	Grain	Stover
1914—*Continued*		%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Red Dent.....	5–14	90	9–14	1/20	13	225	260	4500
Brown County Yellow Dent..	5–14	95	9–15	1/12	76	170	912	2040
Strawberry	5–12	40	9–28	¼	88	277	352	1108
White Australian	5–12	85	8–5	¼	225	448	900	1792
Stooling Brazilian Flour..	5–12	100	9–21	¼	25	1224	100	4896
Bloody Butcher	5–13	80	10–1	¼	164	1661	656	6644
Mexican Black	5–13	40	10–1	¼	20	190	80	760
" June	5–13	95	9–15	1/40	...	631[1]	....	2527
Iowa Silver Mine	7–10	..	9–25	⅛	...	170[1]	....	1363
White Pearl...	7–10	..	9–25	⅛	...	107[1]	....	857
Leaming	7–10	..	9–25	⅛	...	168[1]	....	1341
White Wonder	7–10	..	9–25	¼	...	253[1]	....	1011
Gabarino	5–27	70	10–6	1/10	78	252	780	2520
Sixty Day.....	5–13	95	9–15	1/40	10	18	400	720
Rice Pop.....	5–14	95	9–15	1/40	10	105	400	4200
Sweet	5–13	100	10–1	¼	155	840	620	3360
Eureka	6–22	75	9–19	¼	...	722	....	3088
Chub	5–13	80	9–28	1/20	23	255	460	5100
1915								
Red Dent.....	5–18	95	10–10	⅛	187	273	1496	2184
White "	5–18	70	10–11	1/40	27	100	1080	4000
Brown County Yellow Dent..	5–18	50	10–11	1/20	44	111	880	2220
Reid's Yellow Dent	5–17	95	10–6	⅛	220	301	1760	2408
Maul's Yellow Dent	5–17	95	10–9	⅛	200	497	1600	3976
King Philip....	5–18	95	10–10	⅛	200	317	1600	2536
Chub	5–18	95	10–10	1/16	41	155	656	2480
Strawberry	5–18	..	.....	....	...	...[2]	....	....
"	5–19	70	10–21	⅛	...	...	....	...[2]
Iowa Silver Mine	5–18	95	10–10	1/20	71	409	1420	8180
Elgin	5–18	95	10–10	⅛	81	161	648	1288
Rice Pop	5–18	95	10–11	1/20	11	69	220	1380
Bloody Butcher	5–17	95	10–6	⅛	215	290	1720	2320
" "	5–19	80	10–21	⅛	...	...	....	....
Swadley	5–17	95	10–6	⅛	34	60	272	480
Hickory King..	5–17	95	10–6	⅛	87	560	696	4480
White Australian	5–17	95	10–6	⅛	101	100	808	800
Mexican Black	5–17	95	10–9	⅛	36	62	288	496
Stooling Brazilian Flour..	5–17	95	10–9	⅛	75	400	600	3200
Sweet	5–17	95	10–9	⅛	35	200	280	1600

1—Calculated from green weight. 2—Failed to come up.

TABLE XLIX. SUMMARY, VARIETY TEST OF IMPROVED AMERICAN CORN, PRESCOTT DRY-FARM

Variety	Yields per acre									
	1912		1913		1914		1915		Average	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Reid's Yellow Dent	1224	2990	3920	5912	883	5019	1760	2408	**1992**	**4082**
White Dent	1226	3752	1405	3760	1234	5087	1080	4000	**1236**	**4150**
Red "	....	....	1000	2080	260	4500	1496	2184	**919**	**2921**
Maul's Yellow Dent	....	....	368	744	1226	3816	1600	3976	**1065**	**2845**
Brown County Yellow Dent	....	....	668	1020	912	2040	880	2220	**820**	**1760**
Colorado Yellow Dent	....	....	....	....	900	2624	....	....	**900**	**2624**
Bloody Butcher	....	....	1882	3003	656	6644	860	1160	**1133**	**3602**
King Philip	....	....	2340	5400	300	2496	1600	2536	**1413**	**3477**
Strawberry	....	....	1584	2376	352	1108	....	....	**645**	**1161**
Rice Pop	300	2500	....	....	400	4200	220	1380	**307**	**2693**
Mexican Black	76	1396	332	664	80	760	288	496	**194**	**829**
Sweet	540	7500	3170	3170	620	3360	280	1600	**1152**	**3908**
Elgin	....	....	328	664	....	....	648	1288	**488**	**976**
Sixty Day	....	....	312	936	400	720	....	....	**356**	**828**
Hickory King	....	....	1452	4720	....	....	696	4480	**1074**	**4600**
Colorado White Flint	....	....	....	....	280	1768	....	....	**280**	**1768**
Swadley	....	....	....	....	1100	1344	272	480	**686**	**912**
Chub	....	....	....	....	460	5100	656	2480	**558**	**3790**
White Australian	....	....	....	....	900	1792	808	800	**854**	**1296**
Stooling Brazilian Flour	....	....	....	....	100	4896	600	3200	**350**	**4048**
Mexican June	....	....	....	....	....	2527	....	....	....	**2527**
Iowa Silver Mine	....	....	....	....	....	1363	1420	8180	**710**	**4771**
White Pearl	....	....	....	....	....	857	....	....	....	**857**
Leaming	....	....	....	....	....	1341	....	....	....	**1341**
White Wonder	....	....	....	....	....	1011	....	....	....	**1011**
Gabarino	....	....	....	....	780	2520	....	....	**780**	**2520**
Eureka	....	....	....	....	....	3088	....	....	....	**3088**

and no surer varieties will be found than those obtained from the Indians.

Improved American Varieties: Five varieties including sweet, dent and pop corn were planted in 1912. See Table XLVIII. The heaviest yield was obtained from a plot of Reid's Yellow Dent, a plot of White Dent yielding the next largest amount.

The 1913 corn test included thirteen varieties, the highest yield being secured from a plot of Reid's Yellow Dent, the next best yield coming from a plot of King Philip.

Twenty-five varieties were tested in 1914, the best yield, 3630 pounds of ear corn per acre, coming from a plot of White Dent.

Of the eighteen varieties tested in 1915, the best yield, 1760 pounds of ear corn per acre, was obtained from a plot of Reid's Yellow Dent, a plot of Bloody Butcher coming second, with a yield of 1720 pounds per acre.

In summarizing the test of improved varieties of American corn, yields for a given variety in any one year are calculated by averaging all of the plots of that variety grown in the year specified. As will be seen in Table XLIX, best results were obtained from Reid's Yellow Dent, while King Philip, Bloody Butcher, Hickory King, and Maul's Yellow Dent were promising.

Table XLIX shows an especially heavy yield of earn corn for the season of 1913. The distribution of summer rainfall at this time apparently supports the theory that an excess of moisture during the earlier growing period tends to exaggerate vegetative growth at the expense of grain production. In 1913 the summer rainfall was somewhat delayed, not beginning until after the corn plants had begun to form grain, and, as a result, grain formation was stimulated at the expense of vegetative growth.

FRUIT

To determine the practicability of fruit raising by dry-farming, a small orchard of the following varieties of trees was planted in the spring of 1912:

Apples: King David
Rome Beauty
White Winter Pearmain
Arkansas Black
Gravenstein

Pears:	Sickle
	Bartlett
	Winter Bartlett
	Dannas
	Clap Favorite
Cherries:	Napoleon
	English Morrelo
	Bing
Plums:	Grand Duke
	Burbank
	Washington
Peaches:	Salway
Prunes:	Hungarian

One tree of each of the above varieties was planted, excepting King David apples, of which three trees were set out.

During the winter of 1912 and 1913 some of the trees were girdled by rabbits and were replaced in the spring of 1913 with new stock of the same varieties.

In the spring of 1913 a few grape vines were planted, including principally Concords, with one Mission and one Niagara vine.

Two English walnut trees were planted early in 1913.

On June 26, 1913, each tree received fifteen gallons of water, and each grape vine ten gallons, the only irrigation supplied since planting.

A little fruit was produced by the plums and the grapes in 1915, and all of the trees have made a healthy growth. Fruit production in 1916 and 1917 increased normally.

The moisture content of the orchard plot (see Table L) indicates that, with careful and consistent cultivation, a slight amount of moisture may be stored in the soil, especially in the area below the second foot. In 1911, about thirty days after the land was broken, the soil was so dry and hard below the fifth foot that samples could not be obtained with the soil auger. The condition was improved in 1912, and a sample was secured from the sixth foot, while in 1913, 1914 and 1915, samples to a depth of eight feet were readily obtained. It appears likely that sufficient moisture can be stored in the soil to make production of dry-farmed fruits for home

use practicable, and, after the trees have come into full bearing, one or two irrigations per annum may suffice to make orcharding profitable.

TABLE L. MOISTURE DETERMINATIONS, PRESCOTT DRY-FARM ORCHARD

Date of taking sample	1st ft.	2nd ft.	3rd ft.	4th ft.	5th ft.	6th ft.	7th ft	8th ft.	Yearly Average
9- 3-11	14.28	15.21	9.68	13.36	9.23	.....	.....	.....	12.35
9- 7-12	14.3	17.6	19.30	14.10	9.50	8.30	.....	.....	13.85
5-13-12	17.8	20.10	16.70	16.50	15.30	13.70	13.00	14.90	16.00
9-20-14	8.4	14.40	12.00	11.20	15.20	13.20	15.90	.....	12.90
5-28-15	16.4	20.00	20.20	17.00	17.40	18.50	21.80	22.90	19.28
Avge.	14.24	17.46	15.58	14.43	13.33	13.43	16.90	18.90	14.80
Average for period									15.53

POTATOES

The climate of northern Arizona at an altitude of 5000 feet or more is somewhat favorable to potato growing, and, with suitable soil and ample moisture, large yields can be secured. Market prices

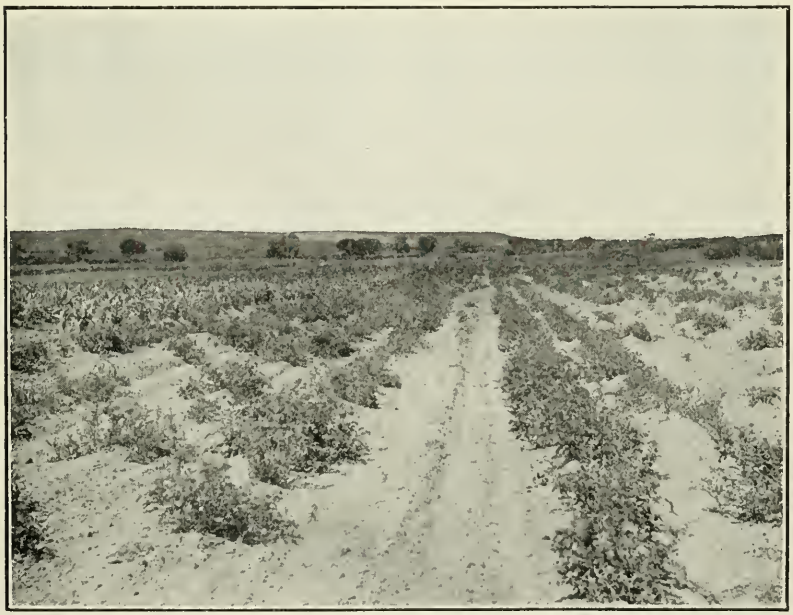

Fig. 29.—Potatoes damaged by potato stem borer, Prescott Dry-farm.

TABLE LI. VARIETY TEST OF POTATOES, PRESCOTT DRY-FARM

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot	Yield per acre
		%		*Acres*	*Pounds*	*Pounds*
1912						
White Star	5–21	90	12–28	1/20	95	1900
" "	5–24	90	12–28	1/8	210	1680
Blue Victor	5–21	90	12–28	1/15	460	6900
Early Rose	5–21	90	12–28	1/15	231	3465
1913						
Wynekoop	5–4	70	11–8	1/4	390	1560
"	5–21	85	10–18	1/8	149	1192
"	5–21	85	10–18	1/20	151[1]	3020
Blue Victor	6–2	20	11–8	1/40	2[2]	80
White Star	6–2	5	.....	1/20	...[2]	....
Irish Cobbler	5–2	60	11–8	1/20	5[2]	100
" "	5–2	70	10–20	1/8	79[2]	632
Early Rose	6–2	75	11–8	1/40	15[2]	600
Red Ohio	5–2	70	10–20	1/20	19[2]	380
1914						
Irish Cobbler	4–21	75	11–28	1/4	101	404
" "	4–24	70	11–21	1/10	38	380
" "	4–25	80	11–21	1/20	26	520
" "	4–25	85	11–28	1/40	9	360
Rural New Yorker	4–24	..	11–28	....	...[2]	....
Carman No. 1	4–24	60	11–28	1/80	16	1280
Red Ohio	4–24	75	11–28	1/80	20	1600
" "	5–27	85	11–28	1/40	22	880
Moore's Early Snowball	4–24	95	11–28	1/40	27	1080
Wrencher's Surprise	4–24	70	11–28	1/40	14	560
Blue Victor	4–24	70	11–21	1/40	26	1040
Peachblow	4–25	60	11–21	1/20	23	460
Rose Seedling	4–25	80	11–21	1/20	32	640
Russet Burbank	4–25	80	11–28	1/20	20	400
Mammoth White Pearl	4–25	25	11–28	1/40	5	200
Mammoth White Pearl	4–25	10	11–28	1/40	½	20
Bonanza	4–24	80	11–21	1/40	21	840
Wynekoop	5–27	85	11–28	1/40	26	1040
1915						
Irish Cobbler	6–1	20	12–14	1/40	12	480
" "	6–1	20	12–14	1/12	10	120
Red Ohio	6–1	40	12–14	1/40	34	1360
Carman No. 1	6–1	30	12–14	1/40	12	480
Vermont Gold Coin	6–1	50	12–14	1/20	50	1000
Compton's Surprise	6–1	40	12–14	1/40	3	120
Russet Burbank	6–1	50	12–14	1/40	39	1560
" "	6–1	20	12–14	1/40	15	600
Mammoth White Pearl	6–1	20	12–14	1/80	1	80
Blue Victor	6–1	20	12–14	1/80	4	320
Peachblow	6–1	20	12–14	1/40	25	1000
Bonanza	6–1	20	12–14	1/40	8	320

1—Irrigated with floodwater. 2—Destroyed by potato beetles.

TABLE LII. SUMMARY, VARIETY TEST OF POTATOES, PRESCOTT DRY-FARM

Variety	1912	1913	1914	1915	Average
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Blue Victor	6900	80	1040	320	**2005**
White Star	1880	....	....	....	**940**
Early Rose	3465	600	....	....	**2032**
Wynekoop	....	1924	1040	....	**988**
Irish Cobbler	....	366	416	300	**270**
Red Ohio	....	380	1240	1360	**745**
Carman No. 1	....	....	1280	480	**880**
Moore's Early Snowball	....	....	1080	....	**1080**
Bonanza	....	....	840	320	**580**
Wrencher's Surprise	....	....	560	....	**560**
Peachblow	....	....	460	1000	**730**
Russet Burbank	....	....	400	1080	**740**
Mammoth White Pearl	....	....	110	80	**95**
Rural New Yorker	....	....	....[1]	....	....
Vermont Gold Coin	....	....	....	1000	**1000**
Compton's Surprise	....	....	....	120	**120**
Rose Seedling	....	....	640	....	**640**

1—Destroyed by potato beetles.

are usually very high, and satisfactory crops of potatoes are probably as profitable as any crop grown at present on northern Arizona dry farms.

In 1912 three varieties of potatoes were planted, including White Star, Blue Victor, and Early Rose. See Tables LI and LII. The largest yield was 6900 pounds per acre from the Blue Victor plot. Seed for this plot was secured in Coconino County where it had been grown for many years and was therefore well acclimatized.

In addition to the varieties tested in 1912, Irish Cobbler, Red Ohio, and Wynekoop potatoes were grown in 1913. The largest yield, 3020 pounds per acre, was from a plot of Wynekoop potatoes which had received an irrigation by floodwater. The two remaining Wynekoop plots yielded considerably more than the other varieties.

Several varieties were added to the test in 1914, including Rural New Yorker, Carman No. 1, Moore's Early Snowball, Wrencher's Surprise, Peachblow, Rose Seedling, Russet Burbank, Mammoth White Pearl, and Bonanza. The largest yield was 1600 pounds per acre obtained from a plot of Red Ohio, Carman No. 1 returning the second largest yield, 1280 pounds per acre.

In 1915 several other varieties previously tested were discontinued, and Vermont Gold Coin and Compton's Surprise were

Fig. 30.—California Club wheat (right) and Koffoid (left), Prescott Dry-farm June 24, 1915.

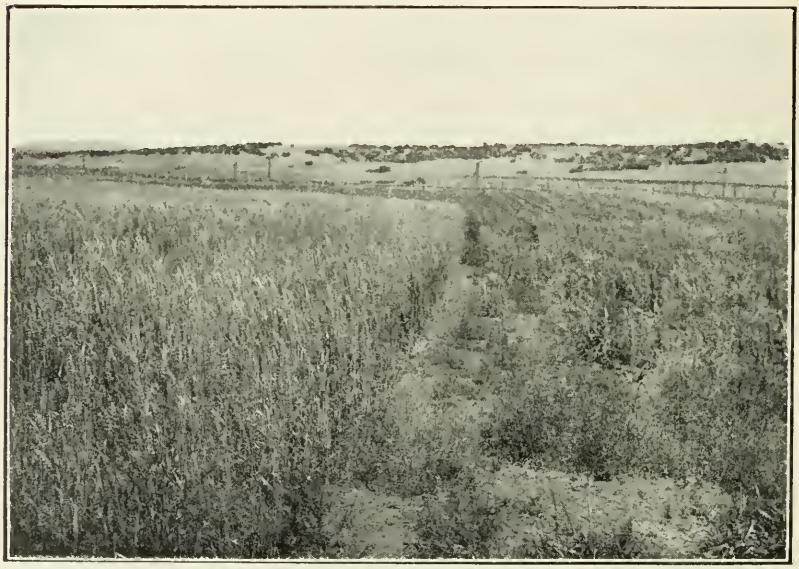

Fig. 31.—Marquis wheat (left) and winter killed barley (right), Prescott Dry-farm, June 24, 1915.

TABLE LIII. VARIETY TEST OF WHEAT, PRESCOTT DRY-FARM

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
					Grain	Straw	Grain	Straw
1913		%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Turkey Red...	9–10	..	6–30	1/8	40	75	320	600
" " ...	10–5	..	7–22	1/7	36	34	252	238
" " ...	10–5	..	.....	....	...	...[1]	....	....
" " ...	10–10	..	7–23	1/4	35	...	140	....
" " ...	11–10	33	7–23	1/4	12	225	48	900
" " ...	3–19	..	.....	....	...	...[6]	....	....
Bluestem	10–5	..	7–8	....	...	...[1]	....	....
"	4–11	..	.....	1/8	3/4	5	6	40
Kubanka	10–5	..	.....	....	...	...[1]	....	....
Club Head....	10–7	..	.....	....	...	...[1]	....	....
Early Baart...	2–9	..	11–7	1/8	...	110	....	880
" " ...	4–11	..	.....	1/8	...	...[2]	....	....
" " ...	4–16	..	.....	....	.	...[3]	....	....
" " ...	5–16	..	....	1/8	.	...[2]	....	....
" " ...	5–20	..	9–4	1/8	...	85	....	680
" " ...	5–21	..	.....	1/20	...	...[4]	....	....
" " ...	5–21	..	.....	1/20	...	...[4]	....	....
" " ...	5–21	..	.....	1/20	...	...[4]	....	....
Spring Turkey	4–16	..	.....	....	...	...[5]	....	....
Gold Coin.....	4–11	..	.....	1/8	...	...[6]	....	....
McOmie	4–11	..	.....	1/8	...	...[7]	....	....
Polish	4–11	70	8–1	1/4	12	40	48	160
Red Russian..	4–11	..	.....	....	...	...	....	....
Hopi	4–11	..	11–4	1/24	2 1/2	3	60	72
"	4–25	..	....	....	...	...[2]	....	....
Red Fife.....	4–11	..	9–9	1/12	...	...	....	....
" "	4–11	70	9–28	1/4	2	7	8	28
Club Head....	4–16	..	.....	....	...	...[8]	....	....
Koffoid	4–16	..	....	....	...	...[6]	....	....
New Zealand Spring	4–11	80	9–28	1/4	30	300	120	1200
White Australian	4–25	..	.....	...	...	...[2]	....	....
1914								
Sonora	10–10	85	6–2	1/4	5	35	20	140
Turkey Red...	9–16	..	6–25	1/4	24	191	96	764
" " ...	9–17	85	6–11	1/8	10	27	80	216
" " ...	10–10	100	6–25	1/4	19	131	76	524
" " ...	11–10	100	6–29	1/4	15	113	60	452
" " C. I. 2998.....	10–6	90	6–28	1/20	12	88	240	1760
Club Head	10–7	..	.....	....	...	...[7]	....	....
Marquis	9–16	95	6–11	1/4	50	302	200	1208
Polish	9–17	95	6–11	1/8	21	73	168	584
Seven Headed Kharkov C. I. 1442	10–6	..	....	1/48	...	...	....	....
Arinaviar C. I. 1355	9–25	85	6–27	3/40	12	88	160	1173
Crimean C. I. 1559	8–25	85	6–27	3/40	20	93	266	1240
	8–25	85	6–27	3/40	16	86	213	1146

1—Winter killed. 2—Died of drouth. 3—Disced Aug. 15. 4—Destroyed by rabbits. 5—Disced Sept. 15. 6—Pastured. 7—Disced Aug. 9.

TABLE LIII—*Continued*

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
					Grain	Straw	Grain	Straw
1914—*Continued*		%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Crimean C. I. 1436	8–25	85	6–25	3/40	15	135	200	1800
Crimean C. I. 1435	9–25	85	6–25	3/40	14	90	173	1200
Ghirka C. I. 1438	8–25	85	6–27	1/40	7	100	280	4000
Bulgarian C. I. 2048	8–25	85	6–26	3/40	23	146	306	1946
Bluestem	10–6	95	6–26	1/48	2	96	96	960
Kubanka	8–25	85	6–28	1/10	14	84	140	840
1915								
Kharkov C. I. 1442	10–12	90	7–21	1/40	8	18	320	720
Kharkov C. I. 1355	10–12	90	7–21	1/80	5	13	400	1040
Arinaviar	10–12	90	7–21	1/40	7	17	280	680
Ghirka C. I. 1438	10–12	90	7–21	1/20	14	27	280	540
Bulgarian C. I. 2048	10–12	85	7–21	1/20	15	31	300	620
Red Fife	10–10	90	7–20	1/10	34	78	340	780
Marquis	9–30	95	7–10	1/8	160	455	1280	3640
"	10–10	95	7–20	1/6	71	121	426	726
White Australian	10–10	60	.....	1/42	...	...[8]	....	....
Early Baart	10–10	70	....	1/11	...	...[8]	....	....
Gold Coin	10–10	65	....	2/11	...	...[8]	....	....
Crimean C. I. 1435	10–12	85	7–19	1/20	17	28	340	560
Crimean C. I. 1437	10–12	80	7–20	1/40	10	17	400	680
Crimean C. I. 1559	10–12	80	7–19	1/12	25	49	300	583
Kubanka	10–12	75	7–20	1/7	41	81	287	567
Bluestem	10–12	95	7–20	1/8	34	73	272	584
Koffoid	9–30	95	7–10	1/8	104	312	832	2496
Minnesota Fife No. 43	9–30	95	7–10	1/8	100	401	800	3208
Turkey Red	10–10	95	7–6	1/8	112	416	896	3328

8—Destroyed by prairie dogs in April.

added. The largest yield was 1560 pounds per acre from a plot of Russet Burbank potatoes. In both 1914 and 1915 considerable damage was done by Colorado potato beetles.

SMALL GRAINS

Wheat: In the fall of 1911 several plots of wheat were planted on virgin land which had been broken in August and September,

but were entirely destroyed by prairie dogs and rabbits during the winter.

Four varieties were planted in the fall of 1912 and fourteen varieties in the spring of 1913. See Table LIII. Hard red winter, semi-hard spring, and soft bread wheats, macaroni wheats, and one plot of Polish wheat were included in the varieties. The best yield was obtained from a plot of Turkey Red planted September 10.

Thirteen varieties were planted in the fall of 1913, including the same classes of wheat as were used the previous year, with the addition of Poulard, a variety known by several names, such as Miracle, Alaska, and Seven-headed. The best yield was from a small plot of Bulgarian C. I. No. 2048.

Better returns were secured in 1915, a plot of Marquis yielding 1280 pounds of grain per acre.

A summary of the variety test of wheat on the Prescott Dry-farm is given in Table LIV. In this table annual yields of a given variety represent the average of all plots of that variety in the year named.

To determine the most favorable date to plant wheat, a number

TABLE LIV. SUMMARY, VARIETY TEST OF WINTER WHEATS, PRESCOTT DRY-FARM

Variety	Yield per acre							
	1913		1914		1915		Average	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Turkey Red	152	435	110	743	896	3328	386	1502
Early Baart	...	...	...	...	...	...	...	....
Bluestem	...	...	96	960	272	584	123	515
Kubanka	...	...	140	840	287	567	142	469
Sonora	...	...	20	140	...	...	20	140
Club Head	...	...	...	...	...	...	...	....
Marquis	...	...	200	1208	853	2183	526	1695
Polish	...	...	168	584	...	...	168	584
Kharkov	...	...	160	1173	360	880	260	1026
Arinaviar	...	...	266	1240	280	680	273	960
Crimean	...	...	195	1382	347	609	271	995
Ghirka	...	...	280	4000	280	540	280	2270
Bulgarian	...	...	306	1946	300	620	303	1283
Red Fife	...	...	...	...	340	780	340	780
White Australian	...	...	...	...	...	...	...	....
Gold Coin	...	...	...	...	...	...	...	....
Koffoid	...	...	...	...	832	2496	832	2496
Minnesota Fife No. 43	...	...	...	...	880	3208	880	3208

TABLE LIV*a*. SUMMARY, VARIETY TEST OF SPRING WHEATS, PRESCOTT DRY-FARM

Variety	Yield per acre 1913	
	Grain	Straw
	Pounds	*Pounds*
Turkey Red	...	....
Early Baart	...	195
Bluestem	6	40
Spring Turkey	...	....
Gold Coin	...	....
McOmie	...	....
Polish	48	160
Red Russian	...	....
Hopi	30	36
Red Fife	4	140
Club Head	...	....
Koffoid	...	....
New Zealand	120	1200
White Australian	...	....

of plots of different varieties were seeded at various times in 1913, 1914, and 1915. Table LV records the results and indicates the desirability of planting in August or early in September.

Table LIII indicates a heavy production of straw, compared with the yield of grain in 1914. This was probably due to the wet spring of 1914 and to thick seeding, the stimulated vegetative growth utilizing available moisture from the soil to such an extent that, upon fruiting, there was insufficient moisture satisfactorily to mature the grain, which was light and shrivelled. While the grain produced in 1914 was insufficient to insure reasonable profits, the possibilities of wheat as a hay crop are indicated.

The production of winter wheat on dry farms in the Great Plains and in the Northwest is usually considered the most profitable branch of the business. Persistent trials with some of the hardiest varieties, however, have failed to indicate that wheat can be profitably grown in the Prescott vicinity without irrigation. Serious winter killing occurs even though the minimum temperatures of winter are seldom very low. Plots planted in early fall occasionally return profitable yields when the snowfall in winter is sufficient and constant enough to prevent winter killing. Wheat should be seeded thinly on dry farms, thirty-five pounds per acre being sufficient.

Oats: In the fall of 1912 two varieties of oats, Texas Red, and

TABLE LV. WHEAT, TIME OF PLANTING TEST, PRESCOTT DRY-FARM

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
					Grain	Straw	Grain	Straw
		%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1913								
Turkey Red...	8–10	90	7–3	¼	180	195	720	780
" " ...	9–10	90	6–30	⅛	40	75	320	600
" " ...	10–5	80	7–22	1/7	36	34	252	238
" " ...	10–5	..	.....	....	...	...[1]	....	....
" " ...	10–10	..	.....	....	...	...[1]	....	....
" " ...	10–10	80	7–23	¼	35	...	140	....
" " ...	11–10	50	7–23	¼	12	22	48	88
Kubanka	10–5	..	.....	....	...	...[1]	....	....
Bluestem	10–5	..	.....	....	...	...[1]	....	....
1914								
Turkey Red...	8–10	85	6–25	¼	18	100	72	400
" " ...	9–10	90	6–25	¼	24	191	96	764
" " ...	10–6	90	6–28	1/20	12	88	240	1760
" " ...	10–10	75	6–25	¼	19	131	76	524
" " ...	11–10	70	6–29	¼	15	113	60	452
Sonora	10–10	50	6–2	¼	5	35	20	140
Club Head ...	10–7	..	....	....	...	...[1]	....	....
Marquis	9–16	80	6–11	¼	50	302	200	1208
Polish	9–17	80	6–11	⅛	21	73	168	584
Kubanka	9–25	85	6–28	1/10	14	84	140	840
Bluestem No. 2998	10–6	95	6–26	1/48	2	20	96	960
Spring Turkey	3–19	..	....	....	...	...[2]	....	....
1915								
Turkey Red...	8–10	95	7–6	⅛	73	220	584	1760
" " ...	9–10	95	7–6	⅛	96	254	768	2032
" " ...	10–10	95	7–6	⅛	112	416	896	3328
" " ...	11–10	95	7–11	⅛	51	185	408	1480
Crimean	10–12	85	7–19	1/20	17	28	340	560
Kubanka	10–12	75	7–19	1/7	41	31	287	217
Bluestem	10–12	95	7–20	⅛	34	73	272	584
Koffoid	9–30	95	7–10	⅛	104	312	832	2496
Club Head....	9–30	..	7–10	⅛	...	...	....	....
Marquis	9–30	95	7–10	⅛	160	455	1280	3640
Minnesota Fife	9–30	95	7–10	⅛	100	401	800	3208

1—Winter killed. 2—Plowed under Aug. 23.

Red oats from Snowflake, were planted, both of which were winter killed. Two varieties, Sixty Day and Red (Snowflake), planted in the spring of 1912, were destroyed by prairie dogs. Six varieties were planted in 1913, the highest yield being only 160 pounds of grain per acre. In 1914 two plots of black oats, an unidentified variety grown near Eagar for a number of years, were tested, but yielded only eight pounds of grain per acre. Three varieties were planted in 1915, all being killed by drought. The production of oats without irrigation in the vicinity of Prescott is very questionable. See Table LVI.

TABLE LVI. VARIETY TEST OF OATS, PRESCOTT DRY-FARM

Variety	Date planted	Date harvested	Size of plot	Yield per plot		Yield per acre	
				Grain	Straw	Grain	Straw
			Acres	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1912							
Texas Red	9–10	....	....	...	...[1]	...	....
Red (Snowflake)	10–7	....	....	...	...[1]	...	....
Sixty Day	4–5	6–10	....	...	...[2]	...	....
Red (Snowflake)	4–5	6–10	....	...	...[2]	...	....
1913							
Black	4–11	11–4	1/8	3/4	5	6	40
"	7–10	11–7	1/8	...	47	...	376
Texas Red	4–16	.....	....	...	...[3]	...	....
" "	7–15	11–7	1/8	...	...[3]	...	....
New Alberta	4–11	....	....	...	...	...	....
Sixty Day	4–16	.....	....	...	...[3]	...	....
" "	7–9	11–7	1/16	10	87	160	1392
Russian	4–11	11–4	1/24	3	11	72	264
Kherson	7–10	11–4	1/8	3 1/4	35	26	280
"	4–16	....	....	...	...[4]	...	....
1914							
Black	4–11	9–28	1/4	2	11	8	44
"	4–20	9–28	1/4	2	7	8	28
1915							
Utah Sixty Day	4–15	....	1/20	...	...[5]	...	....
Texas Red	4–15	....	1/20	...	...[5]	...	....
New Alberta	4–15	.....	1/20	...	...[5]	...	....

1—Winter killed. 2—Destroyed by prairie dogs. 3—Disced Aug. 15. 4—Disced Sept. 18. 5—Killed by drought in June.

Barley: One plot of Six Row barley was planted May 14, 1912, and yielded forty-eight pounds of grain per acre (see Table LVII). One plot each of Six Row and White Hulless barley, planted in the fall of 1912, failed to survive the winter.

In 1913, Black Hulless, Mansury, and Six Row barley were planted early in April, but all were destroyed by drought.

The test in 1914 included Six Row, Black Hulless, White Hulless, Oderbrucker, Utah Winter, and Mansury barley, all of which failed, the greatest yield, forty pounds of grain per acre, coming from the Utah Winter plot.

In 1915 Utah Winter and Black Hulless barley were planted, the former producing 200 pounds of grain per acre.

There is little likelihood of barley withstanding the open winters of the Prescott vicinity, and, when planted in spring, it is apt to be destroyed by drought. Therefore, it is improbable that barley ever will become an important dry-farm crop of the region.

Rye: A plot of rye planted in November, 1911, yielded at the rate of 180 pounds of grain per acre. Spring rye in 1913 yielded no

TABLE LVII. VARIETY TEST OF BARLEY, RYE, EMMER, AND SPELTZ, PRESCOTT DRY-FARM

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
					Grain	Straw	Grain	Straw
1912		%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
White Hulless barley	10–7	..	.....	....	...	...	....	....[1]
Six Row barley	5–14	..	9–30	¼	12	130	48	520
" " "	10–7	..	....	....	...	...	....	....[1]
Rye	11–11	..	7–22	1/6	30	160	180	960
1913								
Black Hulless barley	4–7	..	.....	....	...	...	....	....[2]
Six Row barley	4–11	..	....	⅛	...	...	....	....[2]
" " "	4–11	..	.....	....	...	...	....	....[3]
Mansury "	4–11	..	....	....	...	...	....	....[3]
Spring rye	3–19	..	8–1	¼	...	10	....	40
1914								
Six Row barley	7–10	..	11–7	⅛	...	18	....	144
" " "	4–15	..	....	1/40	...	...	....	....
Black Hulless barley	4–11	..	....	...	....	...	....	....[4]
White Hulless barley	4–15	..	....	1/20	...	...	....	....[2]
Oderbrucker barley	4–11	..	....	...	....	...	....	....[4]
Utah Winter barley	8–25	85	6–28	1/10	4	60	40	600
Mansury barley	4–15	..	.....	1/20	...	...	....	....[5]
Rye	7–10	..	11–7	⅛	...	...	....	....
"	9–17	95	6–11	¼	250	537	1000	2148
Speltz	4–20	95	6–26	1/20	4	18	80	360
Emmer	10–6	..	....	....	...	...	....	....[4]
1915								
Utah Winter barley	10–12	70	7–21	1/20	10	29	200	580
Black Hulless barley	9–30	..	....	⅛	...	...	....	....[1]
Black Hulless barley	10–10	..	....	..	...	...	....	....[6]
Black Winter emmer	10–10	..	....	..	...	...	....	....[6]
Rye	10–10	..	....	..	...	...	....	....[6]
Red Winter speltz C.I.1772	10–12	80	7–19	1/9	38	71	342	639

1—Winter killed. 2—Disced. 3—Killed by drought. 4—Destroyed by rabbits. 5—Failed. 6—Destroyed by prairie dogs.

grain and only forty pounds of straw per acre. One plot in 1914 failed utterly, while a second produced at the rate of 1000 pounds of grain and 2148 pounds of straw per acre. In 1915 the only plot seeded was destroyed by prairie dogs. As a hay crop rye is probably the most promising of any of the small grains. It should be

Fig. 32.—Winter rye, Prescott Dry-farm, June 24, 1915.

planted in early fall at the rate of about thirty pounds of seed per acre.

Emmer: The first plots of emmer and speltz were planted in 1914, one being destroyed by rabbits, while the other, a plot of speltz planted April 20, yielded eighty pounds of grain per acre. Black Winter emmer planted in 1915 was destroyed by prairie dogs, while Red Winter speltz C. I. No. 1772 yielded 342 pounds of grain per acre.

SORGHUMS

While sorghums were introduced into the Southwest comparatively recently, they are already recognized by many as the surest producers of both grain and forage in times of drought. In the following discussion, sorghums will be divided into the two usual classes according to their special adaptation; forage sorghums and grain sorghums.

Forage Sorghums: Amber and Club-top sorghums were grown in 1912, the former satisfactorily maturing, the latter failing to ripen seed.

In 1913 African sorghum and Sudan grass were added to the

Fig. 33.—Club-top on bottom land, Prescott Dry-farm, yield 25,050 pounds per acre green forage.

test, the biggest yield coming from Club-top, which still failed to mature.

Sumac and shallu were included in the experiment in 1914, the biggest yield again being obtained from Club-top.

In 1915 Club-top and Dwarf milo were mixed for ensilage purposes, such a mixture furnishing a large tonnage of green fodder containing a fairly high percentage of grain. Best results were obtained from Sumac, the Club-top and milo mixture coming second. See Table LVIII.

Average yields of all plots of forage sorghums for each year are recorded in Table LIX. The desirability of Sumac, Club-top, and Amber is indicated.

TABLE LVIII. FORAGE SORGHUMS; VARIETY TEST, PRESCOTT DRY-FARM

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
					Grain	Stover	Grain	Stover
		%		Acres	Pounds	Pounds	Pounds	Pounds
1912								
Amber	4–26	..	9–19	¼	105	1125	420	4500
"	5–17	..	10–1	¼	196	1715	784	6860
Club-top	5–18	..	10–7	¼	...	891	....	3564
1913								
Club-top	5–14	80	10–15	⅛	...	435	....	3480
" "	4–30	95	8–16	¼	...	1710	....	6840
African	5–2	20	10–15	¼	...	357	....	1428
Amber	5–14	70	10–15	⅛	34	417	272	3336
Sudan grass	7–12	95	11–4	1/12	12	230	144	2760
" "	7–12	95	9–17	1/160	...	22	....	3520
" "	7–12	95	11–4	1/20	5	120	100	2400
" "	7–9	..	11–7	1/10	3	19	30	190
1914								
Sumac	4–16	95	9–22	¼	186	839	744	3356
"	4–18	60	9–24	¾	675	3717[1]	900	4955
Club-top	4–18	70	9–21	⅜	250	2979'	666	7941
" "	4–17	95	9–22	¼	...	1600	....	6400
Shallu	4–18	100	9–28	1/12	61	154	732	1848
Sudan grass	4–17	95	9–10	¼	21	115	84	460
" "	4–18	95	9–17	¼	357	1227	1428	4908
1915								
Sumac	5–17	100	10–25	¾	...	6254[1]	....	8339
Amber	5–13	100	9–23	½	...	1734'	....	3468
Sudan grass	5–13	100	9–23	¼	...	554	....	2216
Mixed Club-top and milo	5–13	95	9–24	2	...	8453[1]	....	4227

1—Calculated from green weight.

TABLE LIX. SUMMARY, VARIETY TEST OF FORAGE SORGHUMS,

Variety	1912		1913		1914		1915		Average	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
Amber	602	5680	272	3336	...	....	...	3468	291	4161
Club-top	...	3564	...	5160	666	7171	...	....	222	5298
African	...	....	...	1428	...	....	...	....	...	1428
Sudan grass	...	....	69	2218	756	2684	...	2216	275	2373
Sumac	...	....	...	....	822	4156	...	8339	411	6248
Shallu	...	....	...	....	732	1848	...	....	732	1848
Mixed Club-top and milo	...	....	...	....	...	....	...	4227	...	4227

Grain Sorghums: Six varieties of grain sorghums were tested in 1912 (see Table LX), the best yield being produced by Dwarf milo, while plots of Red and Black-hulled White Kafir yielded fairly satisfactory amounts of forage.

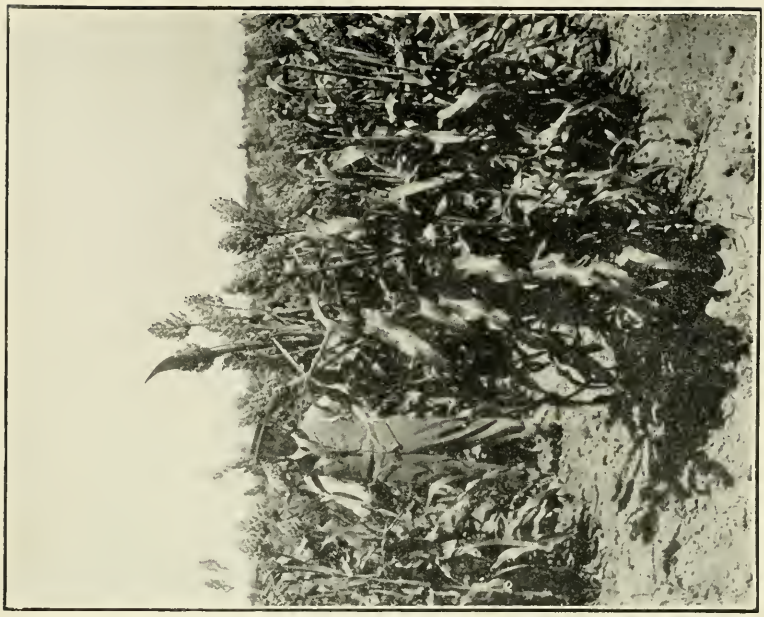

Fig. 35.—Feterita on bottom land, Prescott Dry-farm.

Fig. 34.—Sumac on bottom land, Prescott Dry-farm.

TABLE LX. GRAIN SORGHUMS; VARIETY TEST, PRESCOTT DRY-FARM

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
					Grain	Stover	Grain	Stover
1912		%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Dwarf milo...	5–10	..	10–16	¼	229	757	916	3028
Standard milo	4–16	..	10–7	¼	...	....	....	....[1]
Red Kafir.....	5–20	..	10–8	¼	...	1181	....	4724
Shallu	5–20	..	10–12	¼	177	829	708	3316
Black-hulled White Kafir	5–20	..	10–8	¼	...	612	....	2448
Black-hulled White Kafir	5–17	..	10–9	¼	...	1029	....	4116
Jerusalem corn	5–16	..	10–9	¼	67	359	268	1436
1913								
Feterita	5–2	..	10–17	¼	75	76	300	304
Shallu	5–14	..	10–15	¼	44	107	176	428
Black-hulled White Kafir	5–26	..	10–13	⅛	...	310	....	2480
Black-hulled White Kafir	5–26	..	10–16	⅛	...	706	....	5648
Black-hulled White Kafir	4–30	20	10–16	¼	...	274	....	1096
Black-hulled White Kafir	5–14	70	10–15	⅛	...	270	....	2160
Dwarf milo...	5–21	..	10–13	⅛	312	468	2496	3744
Double Dwarf milo	5–2	40	10–15	¼	103	103	412	412
White milo....	5–23	..	10–14	¼	483	663	1932	2652
Sudan Durra..	5–14	80	10–17	3/40	30	90	400	1200
Kowliang	5–23	90	10–14	1/10	50	250	500	2500
"	5–14	85	10–15	3/40	44	87	586	1160
Red Kafir.....	4–28	100	10–14	¼	...	1165	....	4660
Pink "	5–2	100	10–15	⅛	...	844	....	6752
Jerusalem corn	4–28	85	10–15	¼	110	411	440	1644
1914								
Dwarf milo...	4–18	95	9–27	¼	390	671	1560	2684
Double Dwarf milo	4–18	95	9–27	¼	360	655	1440	2620
Standard milo	4–18	60	9–27	¼	370	600	1480	2400
White "	4–17	50	9–25	¼	220	355	880	1420
White "	4–18	50	9–25	¼	321	650	1284	2600
Kowliang	4–17	95	9–22	1/20	27	169	540	3380
"	4–17	85	9–22	1/40	35	80	1400	3200
"	4–17	100	9–22	¼	...	445	....	1780
Sudan Durra..	4–17	85	9–22	1/40	33	81	1320	3240
Feterita	4–17	15	10–6	¼	21	202	84	808
"	4–18	15	10–1	⅜	410	1230	1093	3280
Pink Kafir....	4–18	95	9–29	1/6	...	627	....	3762
Red "	4–17	90	9–29	¼	...	628	...	2512
White "	4–17	95	10–7	¼	240	630	960	2520
Jerusalem corn	5–27	70	10–6	⅛	140	210	1120	1680
1915								
Standard milo	5–14	75	9–26	⅛	...	487	....	3896
" "	5–14	90	9–26	⅛	...	493	....	3944
Dwarf milo...	5–17	65	10–27	¼	...	1290[2]	...	5160
" "	5–14	95	9–21	¼	...	1185	....	4740

1—Grain eaten by birds. 2—Calculated from green weight.

TABLE LX—*Continued*

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
					Grain	Stover	Grain	Stover
1915—*Continued*		%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Dwarf White milo	5–14	95	9–21	¼	...	1230	....	4920
Dwarf White milo	5–17	95	10–25	¼	...	1026[2]	....	4104
Feterita	5–14	85	9–26	⅛	...	570	....	4560
Shallu	5–14	95	9–26	⅛	...	465	....	3720
"	5–17	95	10–24	⅛	...	456[2]	....	3648
Jerusalem corn	5–14	95	9–26	⅛	...	472	....	3776
Kowliang	5–14	95	9–26	⅛	...	505	....	4040
"	5–17	95	10–24	¼	...	909[2]	....	3635
White Kafir...	5–14	55	9–26	⅛	...	709	....	5672
" " ...	5–13	100	9–24	¾	...	3213[2]	....	4284
" " ...	5–17	100	10–21	⅓	...	2033[2]	....	6099
Red " ...	5–14	70	9–26	⅛	...	1142	....	9136

2—Calculated from green weight.

The test in 1913 included eleven varieties. The most satisfactory yield again was produced by Dwarf milo, White milo coming second.

Fig. 36.—Dwarf milo, Sudan grass, and Sumac on bottom land. Prescott Dry-farm.

Eleven varieties of grain sorghums were tested in 1914, the excellence of Dwarf, Double Dwarf, and Standard milo, and Kowliang being attested.

In 1915 nine varieties, all of which were used for ensilage, were tested, the biggest yield being produced by Red Kafir, White Kafir, and Dwarf milo.

The variety test of grain sorghums is summarized in Table LXI.

TABLE LXI. SUMMARY, VARIETY TEST OF GRAIN SORGHUMS, PRESCOTT DRY-FARM

Variety	Yield per acre									
	1912		1913		1914		1915		Average	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
	P'nds	*P'nds*	*P'nds*	*P'nds*	*P'nds*	*P'nds*	*P'nds*	*P'nds*	*P'nds*	*P'nds*
Dwarf milo..	916	3028	2496	3744	1560	2684	....	4950	1243	3601
Standard milo	....	....	....	....	1480	2400	....	3920	493	2107
Red Kafir "	...	4724	....	4660	....	2512	....	9136	....	5258
Shallu	708	3316	176	428	....	....	....	3684	295	2476
Black-hulled White Kafir	...	2058	...	2846	...	....	....	....	....	2452
Jerusalem corn	268	1436	440	1644	1120	1680	....	3776	457	2134
Feterita	....	....	300	304	588	2044	....	4560	296	2303
Double Dwarf milo	....	....	412	412	1440	2620	....	....	926	1516
White milo..	....	....	1932	2652	1082	2010	....	....	1507	2331
Sudan Durra	....	....	400	1200	1320	3240	....	....	860	2220
Kowliang ...	....	....	543	1830	647	2787	....	3837	397	2818
Pink Kafir...	....	....	....	6752	...	3762	....	....	....	5257
White Kafir..	....	....	...	...	960	2520	....	5351	480	3935
Dwarf White milo	....	....	....	....	....	....	....	4512	....	4512

TABLE LXII. MILO; DEPTH OF PLANTING TEST, PRESCOTT DRY-FARM

Variety	Depth of planting	Date planted	Stand	Date harvested	Yield per acre	
					Grain	Stover
	Inches		%		*Pounds*	*Pounds*
1914						
Dwarf milo.....	6	5-14	80	10-2	1260	3240
" "	5	5-14	90	9-27	1292	2584
" "	4	5-14	85	10-2	1508	3132
" "	2	5-14	70	10-2	1104	2436
1915						
Dwarf milo.....	6	6-5	95	9-29	....	524
" "	5	6-5	95	9-29	....	1098
" "	4	6-5	95	9-29	....	224
" "	2	6-5	95	9-29	....	333

TABLE LXIII. MILO; TIME OF PLANTING TEST, PRESCOTT DRY-FARM

Variety	Date planted	Stand	Date harvested	Size of plot	Yield per plot		Yield per acre	
					Grain	Stover	Grain	Stover
		%		*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1912								
Dwarf milo...	4–10	..	9–18	¼	200	518	800	2072
" " ...	4–16	..	10–7	¼	...	...	...	....
" " ...	5–10	..	10–16	¼	229	757	916	3028
" " ...	6–10	..	10–7	¼	...	353	...	1412
1913								
Dwarf milo...	4–10	..	.....	1/12	...	...	...	....
" " ...	4–28	..	10–16	1/10	91	184	910	1840
" " ...	5–10	..	10–16	3/40	150	150	2000	2000
" " ...	6–10	..	10–16	3/40	60	118	800	1573
1914								
Dwarf milo...	4/10	..	.....	....	...	...[1]	...	....
" " ...	5–10	90	10–6	1/12	67	203	804	2436
" " ...	5–27	90	10–6	1/12	93	202	1116	2424
" " ...	6–10	95	10–6	1/12	55	240	660	2880
1915								
Dwarf milo...	4/10	..	.....	....	...	...[2]	...	....
" " ...	5–10	95	9–26	1/20	...	124	...	2480
" " ...	6–10	70	9–26	1/20	...	91	...	1825

1—Killed by frost, replanted May 27. 2—Killed by frost April 27.

Fig. 37.—Broom corn, Prescott Dry-farm.

To determine the optimum planting depth, four plots of Dwarf milo were seeded in May, 1914, and June, 1915, at depths ranging from two to six inches. The results, recorded in Table LXII, indicate the advantage of deep planting.

To determine the most favorable time to plant, four plots of Dwarf milo were seeded in April, May, and June of 1912, 1913, and 1914, and three plots in 1915. The results, recorded in Table LXIII, indicate the desirability of planting early in May.

MISCELLANEOUS CROPS

Millet: A plot of Hog Millet was planted in 1912, yielding 2000 pounds of forage per acre. For data on millet, rape, and teosinte see Table LXIV.

A small plot of Kursk millet, planted in 1913, yielded at the rate of 3600 pounds of hay per acre.

In 1914 German, Kursk, and Hog millet were planted, low yields being obtained from all plots.

Kursk and German millet were both planted in 1915, the larger yield being obtained from the latter.

TABLE LXIV. VARIETY TESTS OF MILLET, RAPE, TEOSINTE, ETC., PRESCOTT DRY-FARM

Variety	Date planted	Date harvested	Size of plot	Yield per plot		Yield per acre	
				Seed	Forage	Seed	Forage
1912			*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Dwarf Essex rape....	5–16	8–25	¼	..	350	..	1400
Hog millet	5–20	8–24	1/20	..	100[1]	..	2000
Teosinte	5–24	....	....	..	...[2]	..	....
1913							
Kursk millet.....	7–8	9–23	1/30	..	120	..	3600
Teosinte	4–26	10–22	⅛	..	320	..	2560
Dwarf Essex rape....	7–8	....	....	..	...[3]	..	....
1914							
Teosinte	4–10	10–12	¼	..	34	..	136
German millet.....	4–10	9–14	¼	20	321	80	1284
Kursk "	7–10	10–1	¼	5	130	20	520
Hog "	4–17	8–31	¼	..	135	..	540
1915							
Kursk millet.....	6–5	10–1	⅛	..	102[1]	..	816
German "	6–5	10–1	⅛	..	142	.	1136
" "	5–14	.....	¼	..	...[4]	..	....
Dwarf Essex rape.....	7–6	11–8	¼	..	325	..	1300
Turnips	7–6	.....	⅛	..	...[5]	..	....
Buckwheat	5–15	.....	⅛	..	...[5]	..	....

1—Seed eaten by birds. 2—Frozen down in fall when 18 inches high. 3—Failed. 4—Destroyed by rabbits. 5—Killed by drought.

Rape: Dwarf Essex rape was planted in May, 1912, yielding 1400 pounds of dry forage per acre.

Due to drought, a plot of rape failed in 1913.

Dwarf Essex rape was again tested in 1915, yielding 1300 pounds of dry forage.

Teosinte: A plot of teosinte planted in May, 1912, had attained a height of eighteen inches when it was frozen down in the fall.

Teosinte in 1913 produced at the rate of 2560 pounds of dry forage per acre.

In 1914 teosinte failed, yielding only 136 pounds of forage per acre.

Turnips and Buckwheat: Both turnips and buckwheat were tested in 1915, but were unable to withstand the ensuing drought.

CULTURAL PRACTICES FOR DRY-FARMS

Plowing: The best results on the Prescott Dry-Farm have been obtained from deep fall plowing, which assists soil readily to absorb precipitation in winter and early spring. Furthermore, the action of alternate freezing and thawing puts soil in better tilth and assists in the release of plant food that otherwise would not be available. Fall plowing permits the farmer, with the advent of spring, quickly to establish a soil mulch with a minimum loss of moisture, and gives him ample time properly to prepare his seed bed for planting. Subsoiling is unnecessary, but the depth of plowing should be varied annually to prevent formation of a "plow sole." The depth of plowing should not be less than eight inches, and occasionally the soil should be stirred to a depth of ten or twelve inches.

Cultivation: To insure crop production by dry-farming methods, a mulch must be persistently maintained, and the most practical method is cultivation. Variation in depths of cultivations tends to prevent formation of sub-surface crusts. Usually not less than four cultivations will be necessary effectively to control weeds and maintain a mulch. In addition, weeds should be kept out of the rows by hoeing, the entire moisture supply being needed by the plant. It is evident that much moisture will be saved and less labor made necessary if weeds are destroyed when they first appear. Because of the usual drought in June and July, lands should be kept especially clean and well mulched until precipitation

is again abundant. It has been observed on the Prescott Dry-Farm that almost every crop which remained thrifty until the beginning of summer rains in July, yielded profitable returns.

When work is well timed, a harrow satisfactorily maintains a mulch and destroys weeds on summer fallowed land. In one experiment a small area of summer fallowed land was divided into three portions, the first of which was harrowed when weeds were first showing; the second, six days later; and the third portion twelve days after harrowing the first. On the first plot fully 95 per cent of the weeds were killed, while on the second portion not to exceed 60 per cent, and on the third portion less than 25 per cent were destroyed.

The importance of timely operations on dry-farms is not always fully realized. Cultivations delayed for even a day, especially during times of high temperatures and strong winds, may very seriously hinder crop production. Planting should be done at times when the utmost advantage can be taken of precipitation immediately after it falls. Delayed plowing often causes failure, when timely tillage would have sufficed to insure a profitable yield.

The influence of leguminous cover crops on the humus and nitrogen content of the soil is shown in Table LXV. While the data are meagre the value of cover crops is clearly indicated.

Yields are often reduced because of too thick seeding on dry-

TABLE LXV. INFLUENCE OF LEGUMINOUS COVER CROPS ON HUMUS AND NITROGEN, PRESCOTT DRY-FARM ORCHARD

Plot	Crop	1st and 2nd ft.		3rd and 4th ft.	
		Nitrogen	Humus	Nitrogen	Humus
		%	%	%	%
1914; before planting legumes					
No. 1	None	.057	1.46	.039	0.48
" 2	"	.066	1.40	.029	1.08
" 3	"	.055	1.21	.036	0.85
" 4	"	.059	1.68	.031	1.38
1915; after cover crops were turned under					
No. 1	Canada Field peas	.048	1.33	.040	2.07
" 2	Black-eyed cowpeas	.041	1.62	.050	1.12
" 3	Tepary beans	.072	1.38	.035	0.80
" 4	Colorado Stock peas	.098	2.91	048	2.00

farms. The most satisfactory rates of seeding on dry-farms in the Prescott vicinity are stated in Table LXVI.

TABLE LXVI. SUGGESTED RATES OF SEEDING ON DRY-FARMS

	Pounds per Acre
Milo, Kafir, and feterita	3 to 5
Sudan grass	8 to 10
Club-top, sumac, and Amber sorghum	2 to 7
Large beans (Pinks, etc.)	9 to 12
Small beans (Teparies and Navies) and peas	8 to 10
Wheat and small grains	25 to 35
Millet and similar crops	10 to 12
Potatoes (cuttings)	375 to 600

SILOS AND ENSILAGE

Both pit and above-ground silos are in use on the Prescott Dry-farm. The pit silo, twelve feet in diameter and twenty-seven feet deep, was constructed at a cost of approximately fifty dollars, exclusive of labor. A collar, six inches thick and three feet high, the bottom of which is approximately two feet beneath the surface of the ground, was poured first. The pit was then dug to the desired depth and a thin cement wall was poured when the silo was filled in the fall, the fresh ensilage being used in place of a scaffold. Later construction has indicated the desirability of plastering rather than pouring the underground wall. The above-ground silo, 12x20 feet, cost $2.75 for each foot in height.

Silos are virtually necessary to dry-farmers of the region. Ensilage may be fed to horses, cattle, sheep, and swine, any of which may be maintained during times of scarcity of better adapted feeds. A great advantage lies in the fact that crops, raised during a successful year, may be stored in silos and utilized in later years of scarcity. Ensilage has been kept for several years without apparent depreciation, aside from spoilage on the top layer, which takes place very quickly after the ensilage is made.

Satisfactory crops for ensilage are mixtures of Club-top sorghum and Dwarf milo, the former producing a heavy tonnage and the latter a large yield of grain. The importance of quantity rather than quality must not be overestimated, however, as it is probable that from 50 to 75 per cent of the value of most ensilage is in the grain content. Therefore, attention should be paid to the state of maturity of the grain of the ensilage crops. The seed should be as

nearly ripened as possible, while the stalks and leaves are still succulent.

A combination of dry-farming with range stock raising apparently offers the largest profits of any system of dry-farm management capable of adaptation to conditions similar to those of the Prescott Dry-Farm. Dry-farmers with full silos and range stock have a decided advantage over stockmen who depend wholly on the range, or dry-farmers who depend upon crop sales for cash. With this system of management, such crops as beans and potatoes may be grown to sell for cash to shorten the intervals between times of financial income. It is important that dry-farmers realize the limited production of a unit area of their land, and that their farms are ample in size. Table LXVII states capacities of silos of various sizes.

TABLE LXVII. CAPACITY OF SILOS*

Inside diameter	Inside height	Capacity	Number of feeding days	Minimum removed daily
Feet	*Feet*	*Tons*		*Pounds*
8	20	17	121	280
	24	20	142	....
	24	34	130	....
10	28	42	160	525
	32	51	200	....
	26	55	132	....
12	30	67	177	755
	32	74	195	....
	30	91	175	....
14	32	100	193	1030
	36	118	228	....
	32	131	181	....
16	36	155	230	1340
	40	180	270	....
	36	196	...	....
20	40	281	...	....
	44	320	...	....

*From Circular No. 17, Extension Service, University of Arizona, by W. A. Barr.

THE SULPHUR SPRING VALLEY DRY-FARM

The Sulphur Spring Valley Dry-farm'* established by the Arizona Agricultural Experiment Station in August, 1913, contains 160 acres near Cochise on the main line of the Southern Pacific Railroad, which crosses the northwest corner.

The soil is a red loam of varying structure with occasional

*For map of Sulphur Spring Valley Dry-farm see Twenty-eighth Ann. Rept. Ariz. Agric. Exp. Sta., p. 400.

patches of gravel and coarse sand, except where two swales cross the farm. In these a darker, finer, and more productive soil is found. A stratum of "caliche" underlies the entire farm at a depth of one to four feet. Mechanical and chemical analyses are reported in Tables XVI to XIX inclusive.

About seventeen acres in the northeast corner of the farm had been cultivated for several years, a good crop of beans having been grown in 1912. The remainder of the farm was covered with a luxuriant growth of native grasses, especially grama, galleta and bluestem, and yucca. About twenty acres in the northwest corner of the farm and thirty in the southwest corner were broken in the winter of 1913-14; since then the remainder of the farm has been used for pasture.

The need for data having immediate, practicable application was manifest. Accordingly, experimental work done on the Sulphur Spring Valley Dry-farm has been limited to investigations

TABLE LXVIII. MOISTURE DETERMINATIONS, SULPHUR SPRING VALLEY DRY-FARM

Location	1st ft.	2nd ft.	3rd ft.	4th ft.	5th ft.	6th ft.	7th ft	8th ft.
	%	%	%	%	%	%	%	%
January 11, 1915								
Boring 1..	18.5	17.5	13.5	12.8	13.4	13.1	10.7	9.1
" 2..	16.6	15.1	14.8	11.2	13.1	10.2	9.0	5.5
" 3..	12.9	12.1	15.9	16.3	16.8	18.8	16.9	10.2
" 4..	11.3	15.5	15.7	13.0	12.9	11.5	8.0	.....
" 5..	11.8	13.1	11.8	9.35	12.3	7.11	9.3	6.15
" 6..	14.6	13.8	15.0	12.5	14.3	11.1	10.2	8.9
" 7..	15.6	18.2	15.3	12.7	11.8	12.1	10.5	6.8
" 10..	8.0	11.3	13.7	15.7	9.9	9.5	18.5	9.5
July 8-11, 1915								
Boring 1..	5.8	9.5	8.7	11.7	10.1	10.8	9.6	9.9
" 2..	11.7	14.4	14.6	13.0	13.4	9.6	7.0	7.1
" 3..	7.3	13.2	17.0	17.2	12.4	9.8	14.1	10.2
" 4..	8.4	15.3	11.2	14.2	14.9	11.8	11.4	11.5
" 5..	9.8	13.8	11.7	13.2	17.3	12.9	14.9	7.0
" 6..	10.3	11.5	15.2	15.2	15.6	12.7	....	.....
" 7..	9.0	13.8	14.1	13.4	16.2	13.0	....	.....
" 10..	8.6	12.3	17.3	12.0	12.9	14.6	15.9	12.7
July 1-9, 1916								
Boring 1...	9.8	12.0	11.4	9.5	9.4	9.8	8.9	7.9
" 2...	10.5	10.7	10.3	6.7	5.9	8.1	5.1	7.3
" 3...	11.8	11.1	4.8	5.7	4.9	10.6	8.8	7.8
" 4...	11.8	13.2	5.9	8.1	6.1	9.0	13.2	11.3
" 5...	10.4	8.6	4.1	4.0	7.5	7.8	8.8	6.6
" 6...	13.6	10.2	7.8	6.2	6.9	7.5	9.1	10.2
" 8...	8.9	8.5	8.0	7.2	8.2	8.5	5.2	4.9
" 9...	6.1	5.5	3.9	3.6	2.1	5.1	7.5	10.4

concerning conservation of moisture, variety tests, tillage methods, and the most favorable dates, rates and methods of planting; the utilization of occasional floodwaters and supplemental irrigation by pumped waters; and the study of livestock management in its relation to dry-farming.

Moisture determinations were made on a great number of soil samples taken on various dates at depths of eight feet or less. Table LXVIII records the results.

ALFALFA

Turkestan alfalfa was planted in a small plot south of the dwelling-house, October 12, 1914. It was drilled thinly to a depth of four inches, in rows two feet apart, in a well-prepared seed bed. The soil was not uniform and it is interesting to note that the alfalfa came up very readily through the deep mulch of the loamy soil while in the sandy soil, where the mulch was somewhat settled, the stand was poor. About sixty per cent of a normal stand emerged, but winter killing and injury by rabbits reduced the stand by half. The crop was not harvested, but in August, 1915, the yield of seed was carefully estimated as 150 pounds per acre. From this limited trial it appears that alfalfa, grown in rows and cultivated, will return a slight income from the production of seed.

BEANS

Five varieties of beans were planted in May, and six in July, 1914. See Table LXIX. The seed bed for the May plantings was irrigated by laying out small furrows three feet apart, after which two inches of water was run in each furrow. Beans were then planted in the mud and covered to a depth of three inches with dry soil. Prompt germination and rapid growth followed, but, since the beans later appeared to suffer from drought, they were given a three-inch irrigation on June 26. The rainy season began early, and no further irrigation was given except a flood, about four inches deep, which passed over the field July 2. The vines grew to a height of approximately four feet, but blossomed sparingly.

TABLE LXIX. VARIETY TEST OF BEANS, SULPHUR SPRING VALLEY DRY-FARM

Variety	Date planted	Stand	Date harvested	Yield per acre	
				Beans	Straw
		%		*Pounds*	*Pounds*
1914					
Pink	5–29	90	10–17	484	324
Yellow Hopi	5–29	90	10–1	408	1296
White "	5–29	90	10–16	624	1200
Red "	5–29	95	10–16	672	1911
Hopi Lima	5–29	85	10–16	576	912
Dwarf Valentine	7–20	95	10–1	660	528
Trammel	7–24	90	10–12	185	100
"	7–20	59	10–1	500	....
White Navy	7–24	85	10–19	100	150
Small Spanish	7–27	30	9–25	24	72
Pink	7–23	80	9–25	204	156
White Tepary	7–18	..	.....	...	....[1]
" "	7–17	80	10–1	168	200[2]
" "	7–17	80	10–6	180	180[3]
" "	7–17	80	10–7	252	224[4]
" "	7–18	80	10–1	612	576[5]
1915					
Yellow Casa Grande	7–20	80	11–1	154	396
Casa Grande	7–20	90	11–1	528	1584
Pink	7–21	80	11–16	176	396
Colorado Pinto	7–20	95	11–11	308	1232
Bates'	7–20	93	11–11	264	1276
Lady Washington	7–20	95	11–1	484	1276
Red Hopi	7–20	85	11–11	704	1320
White "	7–21	70	10–22	484	1144
Yellow Hopi	7–21	70	10–22	...	....
Bayou	7–20	90	11–1	352	880
White Navy	7–21	70	10–22	308	528
I. I. No. 6	7–21	50	10–22	132	264
I. I. No. 7	7–21	40	10–22	88	352
I. I. No. 8	7–21	15	10–22	22	66
Cream Aztec	7–11	...	9–19	75	....
Tepary	7–17	100	10–6	720	....
"	7–17	100	10–6	784	....
Pink	7–19	90	10–22	167	....
"	7–19	90	10–22	249	....
Hopi Lima	7–21	75	11–22	...	720
I. I. No. 9	7–20	...	11–1	66	220
Dwarf Valentine	7–20	70	11–1	280	640
Black Prolific	7–20	40	11–1	66	176
Small Spanish	7–20	60	11–20	110	242
Tepary	5–1	...	.....	...	....[6]

1—Destroyed by rabbits. 2—Seeded 6 lbs. per acre. 3—Seeded 8 lbs. per acre, 12-inch rows. 4—Seeded 12 lbs. per acre, 12-inch rows. 5—Seeded 8 lbs. per acre, 36-inch rows. 6—Destroyed by grasshoppers.

All of the varieties except Hopi Lima were blighted between September 5 and 20. Pink beans apparently were least, and White Hopi most resistant.

The best yield was obtained from the Red Hopi variety, which produced 672 pounds of beans and 1911 pounds of straw per acre, while the smallest yield was produced by Yellow Hopi beans, which returned 408 pounds of beans and 1296 pounds of straw per acre. Hopi limas grew vigorously throughout the season and set numerous pods, usually containing two, occasionally one or three beans each, and yielded at the rate of 560 pounds of beans and 912 pounds of straw per acre.

The results obtained from July plantings were not so satisfactory, damage by grasshoppers and rabbits materially diminishing yields. The Dwarf Valentine variety, yielding 660 pounds of beans and 528 pounds of straw per acre, gave best results. One plot of White teparies seeded at the rate of eight pounds per acre produced 612 pounds of beans and 576 pounds of straw per acre, and a plot of Trammell yielded 500 pounds of beans.

Six plots of White teparies were planted July 17 and 18 at varying rates, and consequent yields indicate the desirability of thin seeding. The better yield from the plot seeded in thirty-six inch rows at the rate of eight pounds per acre is partly due to more favorable soil and moisture conditions.

Twenty-one varieties of beans were tested in 1915. Most of

Fig. 38.—Dry-farmed milo, melons, and beans, near Cochise, Arizona.

the planting was delayed until July 17 because of the lateness of the summer rainy season.

To destroy the grasshoppers which infested the field, a poisoned bran mash* was scattered broadcast before the beans came up. The result was quite thorough destruction of the insects, but other grasshoppers came in from the outside and did considerable damage to the crop.

The highest yield in 1915 was obtained from two plots of teparies which produced 720 and 784 pounds of beans per acre respectively. Of the larger varieties Red Hopi again led with a yield of 704 pounds per acre. Casa Grande came next with 528 pounds per acre, and White Hopi and Lady Washington were in third place with a yield of 484 pounds per acre, each. Hopi lima beans did not mature because of the short growing season remaining after summer rains began. The vines grew well and were heavily loaded with green pods when frost came.

TABLE LXX. BEANS; TIME OF PLANTING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre	
				Beans	Straw
		%		*Pounds*	*Pounds*
Trammell	4–20	50	9–8	88	286
"	5–10	40	9–8	132	308
"	6–15	5	10–10	33	55
"	7–15	..	.....	...	...[1]

1—Destroyed by grasshoppers.

Trammell beans were used in a test to determine the most favorable date of planting. Plots were seeded April 20, May 10, June 15, and July 15. See Table LXX. The planting of May 10 gave the best returns, yielding 132 pounds of beans per acre. The July 15 plot was destroyed by grasshoppers. Data obtained in this test are insufficient to be considered as an absolute indicator of the best time for planting.

To determine the optimum rate of seeding, six plots of Dwarf Valentine and White teparies were planted at rates varying from four to fourteen pounds per acre. See Table LXXI. The teparies

*The poisoned bran mash was made according to the following formula:

Paris green	1 pound	Water	2½ gallons
Bran	25 pounds		
Corn syrup	1 quart	Lemons	3

were entirely destroyed by rabbits, and the indications from the remaining plots, while indefinite, seem to favor a rather thin planting.

TABLE LXXI. BEANS; RATE OF SEEDING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre		Rate of seeding per acre
				Beans	Straw	
				Pounds	*Pounds*	*Pounds*
Dwarf Valentine..	7–30	Good	11–18	220	110	4
" " ..	7–30	"	11–18	220	220	6
" " ..	7–30	"	11–18	260	198	8
" " ..	7–30	"	11–18	220	308	10
" " ..	7–30	"	11–18	176	198	12
" " ..	7–30	"	11–18	260	220	14

To determine the most practicable spacing of plants five plots of Casa Grande beans were planted July 20, 1915. Rows were three feet apart in all plots, and plants were thinned to thirty-six, twenty-four, twelve, and six inches apart. One check plot was left without thinning. Table LXXII records the results, the best yield being obtained from the plot that was not thinned. Damage by grasshoppers, however, so hampered the growth of beans in this test that data obtained are not especially valuable.

Fig. 39.—Bean harvester in use on Sulphur Spring Valley Dry-farm.

TABLE LXXII. BEANS; SPACING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre		Spacing	
				Beans	Straw	Plants	Rows
		%		*Pounds*	*Pounds*	*Inches*	*Inches*
Casa Grande..	7–20	40	11–16	88	264	36	36
" " ..	7–20	40	11–16	88	264	24	36
" " ..	7–20	40	11–16	110	352	12	36
" " ..	7–20	40	11–16	110	308	6	36
" " ..	7–20	60	11–16	132	352	Not thinned	36

CORN

The winter of 1913-14 was very dry, and, in spring, there was insufficient moisture in the soil to warrant planting, which accordingly, was delayed until the rainy season commenced early in July. The seed bed had been prepared by plowing in the fall of 1913, and by frequent harrowing. Part of the field had been in beans in 1912, and the remainder was newly broken native sod. Experimental work with corn in 1914 was confined to variety testing. All plots were grown under practically the same conditions, with minor variations in soil quality, and were cultivated after every shower of importance, four or five times in all. In Table LXXIII figures under "grain" represent the unshelled corn and "stover" the sun-dried plant after the grain had been removed.

The dry condition of the ground in September, 1914, hastened maturity of most of the corn varieties except Mexican June, which instead of ripening, apparently became inactive until the middle of October, when the moisture condition again became favorable. Renewed growth at this time prevented maturity until the crop was killed by frost. Half Dent Drought Proof, White Australian, and one plot of Strawberry corn were in shallow and somewhat gravelly soil and were most affected by drought, a large percentage of stalks being killed outright. See Table LXXIII. The best plots of White Flint, Hickory King, and Strawberry received a six-inch flood July 2.

In 1915 the highest yield was obtained from a plot of Mexican June, while Saquapu (an Indian variety), White Wonder, and Mohave were the next best varieties. Since 1915 was a rather dry year, there were large numbers of barren stalks in plots of the larger, American varieties: for example, 20 per cent of the stalks in

TABLE LXXIII. VARIETY TEST OF CORN, SULPHUR SPRING VALLEY DRY-FARM

Variety	Date planted	Stand	Date harvested	Yield per acre	
				Grain	Stover
		%		*Pounds*	*Pounds*
1914					
Yellow Hopi	7–18	61	10–15	59	381
Blue "	7–16	72	10–16	297	810
Mixed "	7–16	65	10–28	748	1672
White "	7–18	77	11–5	137	650
White Flint	7–17	57	10–15	384	1472
" "	7–18	68	11–16	3149	6231
Mexican Yellow Flint	7–16	44	11–5	308	1144
Pinedale	7–9	2	10–19	39	99
Sacaton	7–16	72	10–15	352	660
White Australian	7–14	44	10–21	30	1050
Takoorze	7–18	85	10–19	616	1144
Hickory King	7–20	90	11–27	2475	3825
Mexican June	7–16	83	11–27	220	2640
Colorado Yellow Dent	7–15	65	11–19	168	434
Yellow Dent	7–13	52	11–28	440	1705
White "	7–14	50	11–28	420	1650
Half Dent Drought Proof	7–9	68	11–5	83	705
" " " "	7–6	18	11–4	37	161
Reid's Yellow Dent	7–8	78	11–27	450	1710
Maul's Early "	7–18	64	10–21	374	638
Mohave	7–16	66	11–27	1364	1672
Strawberry	7–6	36	11–18	15	225
"	7–14	69	11–18	345	900
"	7–20	79	11–19	2112	2420
Leaming	7–16	71	11–27	560	1372
White Pearl	7–10	66	11–25	864	2376
Iowa Silver Mine	7–13	57	11–28	875	1505
Brazilian Flour Corn	7–17	70	11–28	315	2135
Palakai	7–17	90	11–5	154	506
Sylvia's Early	7–18	44	11–16	336	816
Pop	7–15	86	11–27	455	2375
Bloody Butcher	7–16	56	11–19	525	1500
Pima	7–7	77	10–28	140	1650
Ensilage	7–7	79	11–27	522	1791
White Wonder	7–7	79	11–17	2788	7360
" "	7–11	80	11–25	1640	3715
Swadley	7–21	90	10–19	590	2270
Innominata	7–18	80	11–16	754	1508
Saquapu	7–16	79	11–4	480	480
Heroosquapa	7–16	88	11–4	528	616
White Koescha Kai	7–16	89	11–4	372	806
Mexican Black Sweet	7–17	52	11–4	195	897
1915					
Adams Sweet	7–19	5	11–12	....	....[1]
Mexican Black Sweet	7–19	...	.....	....	....[1]
Swadley	....	...	.....	....	....[1]
"	7–24	50	10–31	88	280
Colorado Yellow Dent	7–24	70	11–8	360	1040
" " "	7–29	90	11–15	748	1276

1—Failed to emerge.

TABLE LXXIII—*Continued*

Variety	Date planted	Stand	Date harvested	Yield per acre	
				Grain	Stover
1915—*Continued*		%		*Pounds*	*Pounds*
Sacaton	7–26	50	10–31	80	96
Mexican June	5–25	80	10–12	1596	3732
Joe Wanderer	5–25	85	10–12	891	4004
Joe Wanderer	4–5	100	9–23	105	2595
Ensilage	5–25	85	10–8	704	4528
"	5–22	70	10–10	297	1463
Bloody Butcher	5–22	85	10–18	576	5280
Kansas White	4–19	85	9–22	572	1628
Queen of Nisna	5–20	90	9–28	704	1716
Pride of Salome	5–20	80	10–12	336	714
Mohave	5–22	85	9–16	1012	1364
White Cap	5–6	90	8–30	484	1518
Pop	8–2	90	11–15	....	1980
Pima	7–29	90	11–10	660	1100
White Australian	8–2	60	11–10	484	616
Reid's Yellow Dent	8–2	85	11–15	....	1936
Maul's Early "	7–29	75	11–10	264	440
Diamond Joe	5–4	85	9–11	660	2992
" "	5–19	85	9–16	484	2332
White Wonder	7–19	80	11–12	1056	4004
Crosby	7–28	...	11–15	....	2176
Sherrod	5–15	80	9–16	528	912
Ranch White	5–19	80	9–28	704	1408
" "	5–4	90	9–22	608	1568
Heroosquapa	5–19	85	9–14	528	792
Freed's	5–20	80	9–28	360	450
Strawberry	4–10	95	8–30	226	847
White Pearl	4–19	80	9–8	136	1259
Hickory King	5–12	90	9–22	462	1716
Saquapu	5–25	85	9–8	1166	3586
1916					
Mexican June	4–16	100	9–21	2490	2207[2]
" "	5–15	80	9–21	1452	1209[2]
" "	7–22	100	11–9	....	3165[2]
White Flint	4–16	100	9–21	3802	2033[2]
" "	5–15	60	9–21	1612	998[2]
" "	7–22	100	11–2	1164	1398[2]
Freed's	4–16	95	9–21	894	1764[2]
"	5–15	50	9–21	500	239[2]
"	7–22	100	11–2	160	2514[2]
White Hopi	4–16	100	9–25	394	220[2]
" "	5–15	50	9–21	94	54[2]
" "	7–22	100	10–24	600	1413[2]
Mohave	4–16	100	9–21	1298	637[2]
"	5–16	50	9–21	176	87[2]
"	7–22	98	10–24	700	2840[2]
Papago Sweet	4–18	80	10–17	764	540[2]
" "	5–16	25	9–21	252	418[2]
" "	7–22	100	11–11	1064	2309[2]

2—Calculated from green weight.

the Mexican June plot were barren, 60 per cent in the Joe Wanderer plot, 27 per cent in the White Ensilage plot, and 30 per cent in the Bloody Butcher plot.

Summer rains in 1916 came early and were well distributed. The superiority of White Flint, Mexican June, and Mohave was again demonstrated, while Papago Sweet, tried for the first time on the Sulphur Spring Valley Dry-farm, produced a good yield.

In Table LXXIV, the average yield per acre of plots of all varieties for each year is shown, and in a separate column fields of all varieties for the three-year period are averaged. White Flint has been the most productive, White Wonder second, Hickory King third, and Mexican June fourth.

TABLE LXXIV. SUMMARY, VARIETY TEST OF CORN, SULPHUR SPRING VALLEY DRY-FARM

Variety	Yield per acre							
	1914		1915		1916		Average	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Yellow Hopi...	59	381	....	....	....	....	59	381
Blue " ...	297	810	....	....	....	....	297	810
Mixed " ...	748	1672	....	....	....	...	748	1672
White " ...	137	650	....	....	363	562	250	606
White Flint....	1766	3851	....	....	2193	1478	1979	2664
Mexican Yellow Flint	308	1144	....	....	....	....	308	1144
Sacaton	352	660	80	96	....	....	216	378
Pinedale	39	99	....	....	....	....	39	99
White Australian	30	1050	484	616	....	...	257	833
Takoorze	616	1144	....	....	....	...	616	1144
Hickory King..	2475	3825	462	1716	....	....	1468	2770
Mexican June..	220	2640	1596	3732	1314	2194	1043	2855
Colorado Yellow Dent....	168	434	554	1158	....	....	361	796
Yellow Dent...	440	1705	....	....	....	...	440	1705
White " ...	420	1650	....	....	....	....	420	1650
Half Dent Drought Proof	60	433	....	....	....	....	60	433
Reid's Yellow Dent	450	1710	....	1936	....	....	225	1823
Maul's Early Dent	374	638	264	440	....	....	319	539
Mohave	1364	1672	1012	1364	718	1188	1031	1408
Strawberry ...	824	1182	226	847	....	...	525	1014
Leaming	560	1372	....	....	....	....	560	1372
White Pearl...	864	2376	136	1259	....	....	500	1817
Iowa Silver Mine	875	1505	....	....	....	....	875	1505

TABLE LXXIV—*Continued*

Variety	Yield per acre							
	1914		1915		1916		Average	
	Grain	Stover	Grain	Stover	Grain	Stover	Grain	Stover
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Brazilian Flour Corn	315	2135	....	....	....	....	315	2135
Palakai	154	506	....	....	....	....	154	506
Sylvia's Early	336	816	....	....	....	....	336	816
Pop	455	2375	....	1980	....	....	227	2177
Bloody Butcher	525	1500	576	5280	....	....	550	3390
Pima	140	1650	660	1100	....	....	400	1375
Ensilage	522	1791	500	2995	....	....	511	2393
White Wonder	2214	5538	1056	4004	....	....	1635	4771
Swadley	590	2270	44	140	....	....	317	1205
Innominata	754	1508	....	....	....	....	754	1508
Saquapu	480	480	1166	3586	....	....	823	2003
Heroosquapa	528	616	528	792	....	....	528	704
Koescha Kai	372	806	....	....	....	....	372	806
Mexican Black Sweet	195	897	....	....	....	....	97	448
Adam's Sweet	....	....	....	....	....	....	....	....
Joe Wanderer	498	3299	....	....	....	....	498	3299
Kansas White	572	1628	....	....	....	....	572	1628
Queen of Nisna	704	1716	....	....	....	....	704	1716
Pride of Salome	336	714	....	....	....	....	336	714
White Cap	484	1518	....	....	....	....	484	1518
Diamond Joe	572	2662	....	....	....	....	572	2662
Crosby	....	2176	....	....	....	....	....	2176
Sherrod	528	912	....	....	....	....	528	912
Ranch White	656	1488	....	....	....	....	656	1488
Freed's	360	450	....	....	518	1506	439	978
Papago Sweet	....	....	....	....	693	1102	693	1102

To determine the optimum time to plant, White Wonder corn was seeded on six dates, as shown in Table LXXV, ranging from March 29 to August 15. A perfect stand was secured in the March planted plot, the soil being moist to within an inch of the surface. In April and May the corn was planted three and one-half inches deep. In June and July a heavy sub-mulch crust was formed, which was broken with a 6-inch pony plow so that the seed might be planted in moist soil. The resulting stand was poor. A shower, occurring just after the July planting, formed a crust on the surface of the soil, which prevented many plants from coming up. The August planting was too late to allow the corn to mature. Table LXXV indicates the desirability of early planting in spite of the drought usually encountered in May and June.

To determine the optimum rate of seeding, six plots of Mixed

TABLE LXXV. CORN; TIME OF PLANTING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre	
				Grain	Stover
		%		*Pounds*	*Pounds*
White Wonder	3–29	100	9–4	880	2338
" "	4–20	90	9–14	792	3210[1]
" "	5–10	90	9–14	880	3153[1]
" "	6–15	25	10–16	286	1584
" "	7–15	40	10–25	440	792
" "	8–15	...	.....	...	....[2]

1—Calculated from green weight. 2—Failed.

Hopi corn were planted on July 29, at rates varying from three to ten pounds of seed per acre. The results, recorded in Table LXXVI, substantiate the popular opinion that thin seeding on dry farms is the most profitable.

TABLE LXXVI. CORN; RATE OF SEEDING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre		Rate of seeding per acre
				Grain	Stover	
				Pounds	*Pounds*	*Pounds*
Mixed Hopi	7–29	Good	11–21	792	1144	3
" "	7–29	"	11–21	1056	1540	4
" "	7–29	"	11–21	858	1254	5
" "	7–29	"	11–21	814	1122	6
" "	7–29	"	11–21	792	1232	8
" "	7–29	"	11–21	770	1254	10

Table LXXVII records data obtained from a depth of planting test in which six plots each of White Wonder and White Hopi corn were seeded on July 31, at depths varying from two and one-half to seven and one-half inches. While White Wonder did not mature, the indications from both varieties are that corn should be planted deeply. The optimum depth, of course, depends upon the moisture content of the soil, experience on the Sulphur Spring Valley Dry-farm indicating that corn should be planted about two inches into moist soil under the dry mulch. When corn is planted early, level culture is preferred, but with later plantings, in the dry months of May and June, listing is the better method.

An experiment in the spacing of corn plants, somewhat similar to that recorded in Table LXXVI, is noted in Table LXXVIII.

TABLE LXXVII. CORN; DEPTH OF PLANTING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre		Depth of planting
				Grain	Stover	
		%		*Pounds*	*Pounds*	*Inches*
White Wonder..	7–31	100	11–16	....	2904[1]	2½
" " ..	7–31	100	11–16	....	3234[1]	3½
" " ..	7–31	100	11–16	....	3102[1]	4½
" " ..	7–31	100	11–16	....	5214[1]	5½
" " ..	7–31	100	11–16	....	4444[1]	6½
" " ..	7–31	100	11–16	....	3894[1]	7½
White Hopi.....	7–31	95	11–16	1012	704	2½
" "	7–31	95	11–16	1056	792	3½
" "	7–31	95	11–16	1100	1012	4½
" "	7–31	95	11–16	880	748	5½
" "	7–31	95	11–16	924	660	6½
" "	7–31	95	11–16	836	572	7½

1—Immature.

Five plots of White Flint corn, planted May 15 in rows thirty-six inches apart, were thinned to distances varying from twelve to thirty-six inches apart in the row. One plot was not thinned, serving as a check. Table LXXVIII indicates the importance of not having dry-farmed plants too close together.

TABLE LXXVIII. CORN; SPACING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Date harvested	Yield per acre		Spacing	
			Grain	Stover	Plants	Rows
			Pounds	*Pounds*	*Inches*	*Inches*
White Flint....	5–15	9–28	768	1488	Not thinned	36
" "	5–15	9–28	744	1608	12	36
" "	5–15	9–28	1104	1152	18	36
" "	5–15	9–28	1056	1152	24	36
" "	5–15	9–28	696	964	36	36

From the first the difficulty of moisture conservation in southern Arizona has been manifest, and opinions regarding the amount of cultivation necessary vary greatly. Table LXIX records a test in which six plots of Ranch White corn, planted July 31, were cultivated eight times or less. While moisture is not easily conserved, the results indicate the desirability of frequent cultivations, best yields having been obtained from the plot cultivated five times.

To determine the advantage of the use of organic fertilizers, two corn plots were covered with barnyard manure early in the

TABLE LXXIX. CORN; CULTIVATION TEST, SULPHUR SPRING VALLEY DRY FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre		Cultivations
				Grain	Stover	
		%		*Pounds*	*Pounds*	
Ranch White.....	7–31	95	11–13	880	2794	0
" "	7–31	90	11–13	880	2420	1
" "	7–31	90	11–13	880	3520	2
" "	7–31	95	11–13	968	3740	3
" "	7–31	95	11–15	1408	5984	5
" "	7–31	90	11–15	968	3696	8

spring of 1915, at the rate of twelve loads per acre; a crop of winter vetch, yielding about five tons of green forage per acre, was plowed under in June on two other plots; and an additional two plots were left without fertilizer. An Indian variety, White Hopi, and an American variety, White Cap, were planted on July 21 under the three conditions of soil treatment. A flood about three inches deep preceded the planting five days, and a uniform stand and rapid growth were noted in all plots. Table LXXX records the results, which favor green manuring.

TABLE LXXX. CORN; FERTILIZER TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre		Fertilizer per acre
				Grain	Stover	
		%		*Pounds*	*Pounds*	
White Hopi...	7–21	90	10–18	1232	1848	Twelve loads manure
" " ...	7–21	90	10–18	1452	1452	Five tons green vetch
" " ...	7–21	90	10–18	418	924	No fertilizer
White Cap....	7–21	90	10–28	594	1408	Twelve loads manure
" "	7–21	90	10–28	715	2145	Five tons green vetch
" "	7–21	90	10–28	143	1133	No fertilizer

To determine the most practicable depth of plowing, nine plots of White Cap and three plots of Leaming corn were planted, from July 31 to August 3, on land which had been plowed at depths ranging from three to twelve inches, with the exception of two plots which were disced only and dynamited only, respectively. Preparation of the seed bed began immediately prior to planting. Table LXXXI clearly indicates the advantage of deep plowing, yields of stover being especially affected. In the dynamited plot one-half stick of 40 per cent strength powder was used every fifty

feet, which was not sufficient to loosen the ground over the entire area. The plots of Leaming corn were planted too late for maturity, and yields were considerably less than should be expected.

TABLE LXXXI. CORN; DEPTH OF PLOWING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre		Depth plowed
				Grain	Stover	
		%		*Pounds*	*Pounds*	*Inches*
White Cap.....	7–31	70	11–19	264	352	Disced
" "	8–1	70	11–19	528	396	3
" "	8–1	70	11–19	484	704	4
" "	8–1	70	11–19	352	836	5
" "	8–1	70	11–19	572	748	6
" "	8–1	70	11–19	528	616	7
" "	8–1	70	11–19	528	1144	8
" "	7–31	70	11–19	484	1232	9
" "	8–2	70	11–19	704	1078	10
Leaming	8–2	80	11–19	110	1276	11
"	8–2	75	11–19	308	1276	12
"	8–3	90	11–19	88	572	Dynamited

All plots were plowed July 30.

POTATOES

In 1914 thirteen varieties of potatoes were planted in rows three feet apart, two inches of irrigating water being run in each furrow previous to the planting, except in the plot of Tennessee Early Triumph, which received no irrigation. After the potatoes had emerged, all plots except the Tennessee Early Triumph were again irrigated twice, the total application being about eight inches of water. In addition, on July 2, a flood six inches deep passed over all plots, except the Tennessee Early Triumph. The best yield, 14,620 pounds per acre, was obtained from a plot of Irish Cobbler potatoes. See Table LXXXII. Some plots were exceedingly small and data from them are not of much value. Four different species of blister beetles were very troublesome and were controlled by spraying repeatedly with arsenate of lead.

Eight varieties were planted in 1915. As indicated by Table LXXXII, the most successful plots were planted in February or March; April, May, and June plantings having been destroyed by drought. Conditions were unfavorable for potato production in 1915. Blister beetles again were serious pests. Because of drought the quality of potatoes uniformly was poor.

TABLE LXXXII. VARIETY TEST OF POTATOES, SULPHUR SPRING VALLEY DRY-FARM

Variety	Date planted	Stand	Date harvested	Yield per acre
1914		%		*Pounds*
Compton's Surprise	4–27	98	10–14	3200
Tennessee Early Triumph	3–27	50	.....	.....[1]
Rural New Yorker	4–30	100	9–22	7260
Mammoth Pearl	4–30	96	9–5	743
Irish Cobbler	4–30	100	9–5	14620
Pink	5–1	95	10–14	1309
Scab Proof	6–10	88	11–2	1248
Wrencher's Surprise	4–30	99	9–26	4500
Unidentified	4–30	100	9–23	525
Russet Burbank	4–30	98	9–26	3719
Rose Seedling	4–30	94	9–26	1090
Bonanza	4–30	98	9–22	2760
Carman	4–30	100	9–22	9500
1915				
Compton's Surprise	2–27	95	7–16	648
Wrencher's Surprise	2–27	95	7–16	624
Scab Proof	2–27	95	7–16	795
Irish Cobbler	2–27	90	7–16	750
Pink	3–26	100	7–16	600
Rural New Yorker	3–26	100	7–16	998
Peachblow	4–20	50	.....	.....[2]
"	6–15	25	.....	.....[2]
White Pearl	5–15	40	.....	.....[2]

1—Failed to mature. 2—Killed by drought.

SMALL GRAINS

Wheat: Four plots of Marquis and three of Turkey Red wheat were planted November 12, 1913. They made a very poor growth during the winter and were eaten down by rabbits until late spring. Late in February four plots of New Zealand wheat were also planted. In May the plots were irrigated, one plot of each variety being left, as a check, without irrigation. Table LXXXIII indicates the advantage gained from irrigation.

In the fall of 1914 fourteen varieties and in the spring of 1915 seven additional varieties of wheat were planted in rows eighteen inches apart. A good stand was obtained from all plots. Three cultivations were given. Varieties that were in the milk or dough stage were considerably damaged by green soldier bugs about the middle of June, all of the grain of Red Russian, Bluestem, and Oregon Club wheat being destroyed. Best results were obtained from Marquis, Early Baart, and Winter Club. See Table LXXXIII. The advantage of fall planting is shown.

TABLE LXXXIII. WHEAT; VARIETY TEST, SULPHUR SPRING VALLEY DRY-FARM

Variety	Date planted	Stand	Date harvested	Yield per acre		Irrigation	
				Grain	Straw	Date	Quantity
1914		%		*Pounds*	*Pounds*		*Inches*
Marquis	11–12	...	6–17	141	30	5–5	6
"	11–12	...	6–17	121	61	5–4	4
"	11–12	...	6–17	91	30	5–4	2
"	11–12	...	6–17	61	30	....	..
Turkey Red	11–12	...	6–20	156	78	5–13	4
" "	11–12	...	6–20	102	85	5–8	2
" "	11–12	...	6–17	104	52	....	..
New Zealand	2–23	90	6–29	100	60	5–15	6
" "	2–23	90	6–29	20	60	5–15	4
" "	2–23	90	6–29	20	60	5–15	2
" "	2–23	90	6–29	17	17	....	..
1915							
Marquis	10–12	100	6–15	1144	1144	....	..
Buffum No. 77	10–8	100	6–17	50	2464	....	..
Koffoid	11–24	100	6–21	375	1063	....	..
Ghirka No. 1438	11–24	100	6–21	383	1067	....	..
Crimean No. 1435	11–24	100	6–21	400	1133	....	..
" " 1559	11–24	100	6–23	333	1200	....	..
" " 1437	11–24	100	6–23	356	1022	....	..
Kharkov No. 1442	11–24	100	6–21	378	1311	....	..
Armenian No. 1355	11–24	100	6–22	333	1022	....	..
Bulgarian No. 2048	11–24	100	6–22	378	1133	....	..
Winter Club	11–25	95	6–15	880	968	....	..
Red Russian	11–28	98	6–30	....[1]	1584	....	..
Red Fife	11–28	100	6–23	396	1276	....	..
Bluestem	3–15	100	6–29	....[1]	1320	....	..
Sonora	3–15	100	6–26	385	319	....	..
"	3–15	100	6–26	165	231	....	..
Oregon Club	3–15	100	6–29	....[1]	1364	....	..
Red Chaff	11–28	100	6–23	660	1276	....	..
Early Baart	1–6	95	6–18	990	1890	....	..
" "	1–6	100	6–14	968	976	....	..
Turkey Red	1–6	100	6–26	270	900	....	..

1—Grain destroyed by insects.

Oats: In 1915 four varieties of oats were tested: namely, Boswell Black, Texas Red, Black Winter, and Sixty Day. The best yield was obtained from Texas Red, with Black Winter second. Because of late planting, growth of Sixty Day oats was not rapid. Considerable damage was done by grasshoppers. See Table LXXXIV.

All 1916 oat plots were destroyed by grasshoppers.

Barley: Three varieties of barley were planted in 1915, common Six Row, Black Hulless, and White Hulless. One plot of Six Row and the White Hulless plot were completely destroyed by

TABLE LXXXIV. OATS; VARIETY TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre	
				Grain	Straw
		%		*Pounds*	*Pounds*
Boswell Black	11–24	97	6–22	63	650
Texas Red	11–25	60	6–16	296	298
Black Winter	11–25	60	6–15	232	212
Sixy Day	3–15	100	.....	...	...

rabbits. See Table LXXXV. The Six Row barley was planted in October under favorable conditions. It grew rapidly, and, late in December, when eight inches to a foot high, was considerably injured by rabbits. By the middle of February it had been eaten to the ground, apparently beyond recovery, but warm weather late in February and some light showers forced one plot into renewed, vigorous growth. The seed was not treated and there was considerable smut.

TABLE LXXXV. BARLEY; VARIETY TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre	
				Grain	Straw
		%		*Pounds*	*Pounds*
Six Row	10–8	95	6–15	969	918
" "	10–10	..	....	...	...[1]
White Hulless	11–25	..	....	...	...[1]
Black Hulless	11–25	75	6–15	420	672

1—Destroyed by rabbits.

Table LXXXVI records results from four plots of spring planted Six Row barley which was thinned to various distances.

TABLE LXXXVI. BARLEY; SPACING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Date harvested	Yield per acre		Spacing	
			Grain	Straw	Plants	Rows
			Pounds	*Pounds*	*Inches*	*Inches*
Six Row	3–15	6–26	165	594	Not thinned	24
" "	3–15	6–26	264	924	Not thinned	12
" "	3–15	6–26	99	198	15	24
" "	3–15	6–26	132	264	8	24

Emmer: On November 12, 1913, five plots of Black Winter emmer were planted. The growth during the winter was meagre and eaten down by rabbits. Irrigation, to depths varying from two to six inches, were given on four plots, one being left as a check. Table LXXXVII records the results. One plot of Black Winter and one of White Spring emmer were planted in November, 1914. Both plots grew well and gave promise of fair yields until the grain of the White Spring emmer was destroyed by green soldier bugs.

TABLE LXXXVII. TEST OF EMMER, SPELTZ, AND RYE, SULPHUR SPRING VALLEY DRY-FARM

Variety	Date planted	Date harvested	Yield per acre		Irrigation	
			Grain	Straw	Date	Quantity
1914			*Pounds*	*Pounds*		*Inches*
Black Winter emmer	11–12	6–23	110	55	5–18	6
" " "	11–12	6–26	111	56	5–18	6
" " "	11–12	6–26	111	37	5–19	4
" " "	11–12	6–26	87	38	5–17	2
" " "	11–12	6–20	88	22	....	..
Red Winter speltz, C. I. 1772	11–12	6–23	150	50	5–18	6
" " " " "	11–12	6–23	95	38	5–20	4
" " " " "	11–12	6–23	120	30	5–20	2
" " " " "	11–12	6–20	100	50	....	..
1915						
Black Winter emmer	11–10	6–24	.572	968	....	..
Red Winter speltz, C. I. 1772	10–12	6–23	1628	1540	....	..
" " " " "	11–24	6–21	633	633	....	..
White Spring emmer	11–28	6–29	...	1760	....	..
Winter rye	10–8	6–14	572	1012	....	..

In 1915 all stands of grain were 100 per cent.

Speltz: Four plots of Red Winter speltz, C. I. No. 1772, were planted November 12, 1913. Three plots were irrigated to a depth of two to six inches, one plot being left as a check. The results were not encouraging, the highest yield being 150 pounds of grain per acre. In the fall of 1914 two plots of Red Winter speltz, C. I. No. 1772, were planted October 12 and November 24, the better one yielding 1628 pounds of grain per acre, which indicates that this crop may sometimes prove of value. See Table LXXXVII.

Rye: One plot of Winter rye was planted October 8, 1914. The season was quite favorable and a vigorous growth resulted. The crop was eaten down by rabbits during the winter but in spring recovered quite fully. The rye was harvested June 14, 1915, yielding 572 pounds of grain and 1012 pounds of straw per acre. The

grain was badly shrunken because of insufficient moisture in late spring. See Table LXXXVII.

SORGHUMS

The sorghums are well adapted to Sulphur Spring Valley conditions, being able to withstand long periods of drought, and to recover and resume growth when the moisture supply is again abundant. That sorghums are surer crops for dry-farming than corn is illustrated by results from one plot each of Early Amber sorghum and Half Dent Drought Proof corn, which, when grown together in 1914, produced at the rate of 360 pounds of heads and 260 pounds of stover per acre and 37 pounds of ears and 161 pounds of stover per acre, respectively. The soil in these plots is approximately two feet deep. During the latter part of August and September it was quite dried out. In October when moisture had again become ample the sorghum revived after much of the corn was dead. Under continuous growing conditions, however, corn often yields more than sorghums, as illustrated by results from two adjacent plots of Feterita and Mohave corn, grown, in 1914, on clay loam soil underlaid by a clay subsoil, which retained sufficient moisture to keep both crops in a growing condition throughout the dry period. The corn yielded at the rate of 1364 pounds of ears and 1672 pounds of stover per acre, while Feterita produced 1085 pounds of stalks.

Six varieties of grain sorghums were planted in July, 1914. Best yields were obtained from plots of Feterita and Dwarf milo. Shallu and Black-hulled White Kafir both failed to mature because of the shortness of the frost-free season remaining after they were planted. See Table LXXXVIII.

Seven varieties of grain sorghums were planted in 1915, on dates ranging from April 23 to July 31. The best yield was obtained from a plot of African Kafir planted May 25. The next highest yield was from a plot of Standard Milo which, however, failed fully to mature.

All grain sorghums in 1916 were grown for ensilage, best results being obtained from a plot of Dwarf Kafir planted March 17.

Two varieties of sweet sorghum, Club-top and Early Amber, were planted in July 1914. See Table LXXXIX. Club-top failed to mature but yielded satisfactory quantities of green forage. One

Fig. 40.—Dwarf milo, grown near Cochise, Arizona, 1913.

Fig. 41.—Shallu, grown near Cochise, Arizona, 1913.

TABLE LXXXVIII. VARIETY TEST OF GRAIN SORGHUMS, SULPHUR SPRING VALLEY DRY-FARM, 1914 AND 1915

Variety	Date planted	Stand	Date harvested	Yields per acre	
				Heads	Stover
		%		*Pounds*	*Pounds*
1914					
Kowliang	7–8	65	10–9	80	432
White milo	7–9	80	10–28	500	2684
Dwarf "	7–13	85	10–29	1012	2112
" "	7–16	80	10–28	470	735
" "	7–16	70	10–28	414	3212
" "	7–25	80	11–16	128	960
Feterita	7–16	70	10–28	401	2301
"	7–16	50	10–5	350	1105
"	7–16	68	11–18	252	1086
"	7–16	60	10–1	....	1084
"	7–18	50	10–17	....	948
"	7–18	70	11–16	1215	3310
"	7–18	50	11–16	308	619
"	7–20	80	10–29	592	816
Shallu	7–18	100	11–27	....	2400
"	7–27	70	11–28	....	1590
Black-hulled White Kafir	7–15	80	11–29	....	1664
" " "	7–16	75	10–28	....	2392
1915					
Feterita	7–30	97	11–15	900[1]	2393
"	7–31	95	11–15	860[1]	1243
"	5–22	...	10–8	288	1224
Kowliang	5–22	90	8–30	384	2592
"	7–28	88	11–15	260	416
"	5–25	90	9–15	572	1332
Standard milo	5–25	89	11–18	1947[1]	3857
" "	5–22	77	10–12	344	2368
" "	4–23	80	9–4	....	2640
Dwarf milo	7–31	90	11–15	640	853
" "	5–4	80	9–8	....	3256
Shallu	5–25	85	10–23	690[1]	771
"	5–25	85	9–26	472[1]	509
Black-hulled White Kafir	4–30	80	10–23	....	8184
" " "	5–19	70	11–5	701[1]	1611
African Kafir	5–25	85	10–30	2926	4466

1—Calculated from green weight.

plot of Early Amber produced 488 pounds of heads per acre and 1600 pounds of stover.

In 1915 Sumac was grown in addition to Early Amber and Club-top. The highest yield was from a plot of Club-top planted May 22, which returned 1552 pounds of heads and 4039 pounds of stover per acre. Again Early Amber was the only variety which fully matured.

In 1916 the forage sorghums were grown for ensilage, best

TABLE LXXXVIII-a. TEST OF GRAIN SORGHUMS, SULPHUR SPRING VALLEY DRY-FARM, 1916

Variety	Date planted	Stand	Date harvested	Green forage per acre
		%		*Pounds*
" "	4–17	15	10–11	2360
Dwarf Kafir	3–17	100	9–22	10530
" "	5–18	60	10–11	4100
" "	7–23	100	10–23	5680
Feterita	4–15	40	9–22	1417
"	5–16	40	9–23	450
"	7–23	100	10–30	9504
"	7–23	80	11–7	2496
Dwarf milo	4–15	50	9–22	2160
" "	5–18	20	9–23	1600
" "	7–23	100	10–16	5784
Standard milo	4–15	60	9–22	1620
" "	5–16	10	9–23	1650
" "	7–21	100	10–16	6930
Milliken's sorghum	7–23	80	11–11	610

TABLE LXXXIX. VARIETY TEST OF FORAGE SORGHUMS, SULPHUR SPRING VALLEY DRY-FARM

Variety	Date planted	Stand	Date harvested	Yield per acre	
				Grain	Stover
1914		%		*Pounds*	*Pounds*
Club-top	7–20	100	11–27	...	3570[1]
"	7–18	100	11–27	...	3283[1]
"	7–18	100	10–29	...	2108[1]
"	7–20	100	11–27	...	3752[1]
"	7–20	100	11–28	...	2593[1]
Early Amber	7–6	65	10–18	360	520
" "	7–16	50	10–16	...	1905
" "	7–24	50	11–16	488	1600
" "	7–16	50	10–17	...	610
1915					
Early Amber	Volunteer	70	10–15	...	2400
" "	7–26	85	11–20	...	2048
" "	4–19	80	8–31	616	2860
" "	8–3	60	11–20	...	1075[1]
" "	7–29	75	11–15	...	2080
Club-top	5–22	85	11–16	1552	4039[1]
"	7–26	80	10–28	...	1909[1]
Sumac	5–12	75	11–8	...	1240[1]
1916					
Club-top	4–15	10	10–17	...	1372[1]
"	5–18	10	10–18	...	689[1]
"	7–21	15	10–18	...	2289[1]
Early Amber	4–15	10	9–22	...	770[1]
" "	5–18	5	10–18	...	424[1]
" "	7–21	95	10–19	...	657[1]

1—Calculated from green weight.

Fig. 42.—Feterita, Sulphur Spring Valley Dry-farm, 1914.

Fig. 43.—Club-top, Sulphur Spring Valley Dry-farm, 1914.

yields being obtained from plots of Club-top, though no yield was satisfactory.

To determine the optimum depth of plant Dwarf milo, six plots were seeded July 19, 1915, at depths ranging from two and one-half to seven and one-half inches. The results, tabulated in Table XC, indicate the desirability of fairly deep planting. Experience indicates that seed should be planted well into moist soil, though, of course, a good stand is rare on a plot which has been seeded to a depth of six inches or more.

TABLE XC. MILO; DEPTH OF PLANTING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre		Depth planted
				Heads	Stover	
				Pounds	*Pounds*	*Inches*
Dwarf milo	7–19	Good	11–15	468	572	2½
" "	7–19	"	11–15	728	364	3½
" "	7–19	"	11–15	754	390	4½
" "	7–19	"	11–15	728	546	5 ½
" "	7–19	Fair	11–15	676	468	6½
" "	7–19	"	11–15	624	442	7 ½

Six plots of Dwarf milo were planted July 30, 1915, to determine the optimum rate of seeding. From three to ten pounds were sown per acre and results clearly indicate the desirability of light seeding. See Table XCI.

TABLE XCI. MILO; RATE OF SEEDING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Date harvested	Yields per acre		Rate of seeding per acre
			Grain	Stover	
			Pounds	*Pounds*	*Pounds*
Dwarf milo	7–30	11–21	528	1122	3
" "	7–30	11–21	484	924	4
" "	7–30	11–21	396	660	5
" "	7–30	11–21	352	616	6
" "	7–30	11–21	308	616	8
" "	7–30	11–21	396	1144	10

Table XCII records results of an experiment to determine the proper amount of cultivation. Six plots of Dwarf milo were planted on July 31, 1915, and cultivated from one to eight times, with the exception of one plot that was left as a check and without

cultivation. The biggest yield was from the plot cultivated twice. The next highest yields were from plots cultivated five and eight times, respectively, and indications are that cultivations should be fairly frequent.

TABLE XCII. MILO; CULTIVATION TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre		Cultivations
				Grain	Stover	
		%		*Pounds*	*Pounds*	
Dwarf milo.....	7–31	100	11–12	572	924	0
" "	7–31	100	11–12	572	836	1
" "	7–31	100	11–12	836	1364	2
" "	7–31	100	11–12	572	1364	3
" "	7–31	100	11–12	748	1364	5
" "	7–31	100	11–12	748	1584	8

Results of an experiment to determine the proper spacing of Milo plants is recorded in Table XCIII. Six plots of White milo were planted May 22, 1915, and six plots of Dwarf milo on July 22. The data are somewhat conflicting, due to uncontrollable differences of conditions, but indicate in general the desirability of close spacing of plants, which is contradictory to other observations.

TABLE XCIII. MILO; SPACING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Date harvested	Yield per acre		Spacing	
			Grain	Stover	Plants	Rows
			Pounds	*Pounds*	*Inches*	*Inches*
White milo....	5–22	10–12	264	2244	36	36
" "	5–22	10–12	198	2486	24	"
" "	5–22	10–12	176	2288	18	"
" "	5–22	10–12	198	2926	12	"
" "	5–22	10–12	176	2860	6	"
" "	5–22	10–12	319	3377	Not thinned	"
Dwarf milo....	7–22	10–15	968	*	36	"
" "	7–22	10–15	1056	*	24	"
" "	7–22	10–15	1320	*	18	"
" "	7–22	10–15	1584	*	12	"
" "	7–22	10–15	1584	*	6	"
" "	7–22	10–15	1584	*	Not thinned	"

*Data missing.

To determine the effect of organic fertilizers, three plots of Dwarf milo were planted July 21, 1915, one having been fertilized

with twelve loads of barnyard manure per acre; another with five tons of green vetch per acre; and the third having received no fertilizer. See Table XCIV. Crusting of the surface soil, because of a shower which fell soon after planting, prevented seed from coming up in the plot which had been green manured. The manured plot returned a slightly heavier yield than the unfertilized.

TABLE XCIV. MILO; FERTILIZER TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date	Stand	Date harvested	Yield per acre		Fertilizer
				Heads	Stover	
		%		*Pounds*	*Pounds*	*Per acre*
Dwarf milo	7–21	85	11–5	616	1980	12 loads manure
" "	7–21	80	11–5	506	1650	None
" "	7–21	..	....	...	....[1]	5 tons green vetch

1—Failed to emerge.

To determine the optimum depth to plow, twelve plots of Dwarf milo were planted July 31, 1915. One plot previously had been disced and another dynamited with a half stick of 40 per cent strength powder placed every fifty feet. The dynamited ground was not well loosened, and about three times as many charges should have been used. The remaining ten plots were plowed July 30, at depths ranging from three to twelve inches. The best yields were obtained from plots which had been deeply plowed. See Table XCV.

TABLE XCV. MILO; DEPTH OF PLOWING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Stand	Date harvested	Yield per acre		Depth plowed
				Heads	Stover	
				Pounds	*Pounds*	*Inches*
Dwarf milo.....	7–31	Good	11–20	416	676	3
" "	7–31	"	11–20	494	546	4
" "	7–31	"	11–21	468	624	5
" "	7–31	"	11–20	468	676	6
" "	7–31	"	11–20	468	624	7
" "	7–31	"	11–20	650	910	8
" "	7–31	"	11–20	910	1482	9
" "	7–31	Fair	11–20	624	1014	10
" "	7–31	Poor	11–20	624	910	11
" "	7–31	"	11–20	468	702	12
" "	7–31	Fair	11–20	364	468	Disced
" "	7–31	Poor	11–20	364	572	Dynamited

All plots plowed July 30.

Fig. 44.—Dry-farmed Kafir, planted thinly, and withstanding drought. Grown near Cochise, Arizona, 1913.

Fig. 45.—Dry-farmed Kafir, planted too thickly, and suffering from drought. Grown near Cochise, Arizona, 1913.

A plot of Sudan grass was planted July 20, 1914, and yielded at the rate of 765 pounds of seed and 7290 pounds of hay per acre. Five plots planted in 1915, on dates ranging from April 31 to August 3, yielded an average of about one ton of hay per acre, the best plot returning 924 pounds of seed and 5808 pounds of hay. Three plots were planted in 1916, in April, May, and July, respectively, with poor success. Two cuttings were obtained from each plot, the best one yielding less than one-half ton of hay per acre. See Table XCVI.

TABLE XCVI. SUDAN GRASS; DATE OF PLANTING TEST, SULPHUR SPRING VALLEY DRY-FARM

Date planted	Stand	Date harvested	Yield per acre	
			Seed	Hay
	%		*Pounds*	*Pounds*
7–20–1914	75	11–25	765	7290
5–22 "	75	10–9	924	5808
4–31–1915	75	9–16	180	1980
5–22 "	80	9–16	...	2376
7–29 "	..	11–15	...	2080
8–3 "	20	11–20	...	1000
4–15–1916	35	9–11	...	219[2]
		11–10[1]		213[2]
5–18 "	5	7–25	...	860[2]
		11–10[1]		63[2]
7–21 "	95	9–25	...	156[2]
		11–7[1]		287[2]

1—Second cutting. 2—Calculated from green weight.

Table XCVII records results obtained from an experiment to determine the proper spacing of Sudan grass plants. All plots except one which was broadcasted, were planted July 30 in rows rang-

TABLE XCVII. SUDAN GRASS; SPACING TEST, SULPHUR SPRING VALLEY DRY-FARM, 1915

Date planted	Stand	Date harvested	Hay per acre	Spacing
	%		*Pounds*	
7–30	65	11–18	880	Broadcast
7–30	90	11–18	2640	Rows 6 in.
7–30	90	11–18	2640	" 12 "
7–30	85	11–18	1463	" 24 "
7–30	85	11–18	821	" 36 "
7–30	85	11–18	413	" 48 "

ing from six to forty-eight inches apart. The highest yields were from the thicker seedings.

Dwarf broom corn was tested in both 1914 and 1915. The yield in 1914 was 392 pounds of brush and 488 pounds of stover, the quality and length of brush being quite satisfactory for broom making.

In 1915, planting was delayed until July 22, too late to satisfactorily mature the brush, which was of inferior quality and only twelve or thirteen inches long. See Table XCVIII.

TABLE XCVIII. TEST OF BROOM CORN, SULPHUR SPRING VALLEY DRY-FARM

Variety	Date planted	Stand	Date harvested	Yield per acre	
				Brush	Stover
		%		*Pounds*	*Pounds*
1914					
Dwarf broom corn	7–9	78	10–27	392	488
1915					
Dwarf broom corn	7–27	70	11–15	...	1500

MISCELLANEOUS CROPS

Millet: Four plots of German and two of Hog millet were planted in 1914. The best yield was obtained from a plot of the former variety receiving three inches of floodwater. In this plot rows were twelve inches apart. The next best crop was made on a plot in which the rows were three feet apart, and which was culti-

TABLE XCIX. VARIETY TEST OF MILLET, SULPHUR SPRING VALLEY DRY-FARM

Variety	Date planted	Stand	Date harvested	Yield per acre	
				Seed	Hay
		%		*Pounds*	*Pounds*
1914					
German	7–18	100	10–16	...	1080[1]
"	7–18	90	10–16	...	1000[2]
"	7–21	85	10–29	...	1440[3]
"	7–18	100	10–17	...	2288[4]
Hog	7–18	90	10–10	518	1064[5]
"	8–10	...	.....	...	....[6]
1915					
Hog	5–22	...	.....	...	....[7]

1—Rows 12 inches apart; 12 pounds seed per acre. 2—Rows 12 inches apart; 8 pounds seed per acre. 3—Rows 36 inches apart; cultivated four times. 4—Rows 12 inches apart; received 3 inches floodwater. 5—Received 4 inches floodwater. 6—Destroyed by grasshoppers. 7—Destroyed by birds.

vated four times. See Table XCIX. The August planting of Hog millet was destroyed by grasshoppers.

The 1915 planting of millet failed. Neither German nor Kursk millet came up because of drought, and the plot of Hog millet was destroyed by birds.

Ribbon Cane: Three plots of Ribbon cane were planted in May, 1915. The results, recorded in Table C, are encouraging, and it is not unlikely that Ribbon cane may become an important forage crop for Southern Arizona dry-farmers.

TABLE C. TEST OF RIBBON CANE, SULPHUR SPRING VALLEY DRY-FARM
1915

Variety	Date planted	Stand	Date harvested	Yield per acre dry fodder
		%		*Pounds*
Ribbon Cane	5–25	80	11–16	4400
" "	5–25	80	11–6	3779[1]
" "	5–22	90	11–16	3328[1]

1—Calculated from green weight.

Peas: Two plots of Canada field peas were planted in 1914 The first one, planted July 18, failed because of warm weather and grasshoppers. See Table CI. A light stand was secured in the plot planted in August, very little growth occurring during warm weather. With the cooler weather of fall, rapid growth took place, the vines reaching a height of about four feet by the middle of December, and a yield of 1000 pounds of hay was obtained.

In 1915 both Canada field and Colorado stock peas were planted with somewhat negative results. The summer season in Sulphur Spring Valley is too warm for satisfactory growth of field

TABLE CI. VARIETY TEST OF PEAS, SULPHUR SPRING VALLEY DRY-FARM

Variety	Date planted	Stand	Date harvested	Yield per acre	
				Seed	Straw
		%		*Pounds*	*Pounds*
1914					
Canada Field	7–18	10	.....	..	....[1]
" "	8–10	33	12–31	..	1000
1915					
Canada Field	7–22	90	11–22	48	696
" "	5–12	80	.....	..	....[2]
Colorado Stock	5–12	80	.....	..	....[2]

1—Failed. 2—Destroyed by rabbits.

peas, which should be planted early in February or late in August.

Cowpeas: A plot of Whippoorwill cowpeas was planted July 22, 1914, and produced a light yield of seed and a fairly satisfactory amount of hay. See Table CII. In 1915, two plots of Whippoorwill, one of White, and one of Black-eyed cowpeas were planted, and in no case was the yield especially high. As a soil renovator, however, and to furnish pasture, the earlier varieties of cowpeas, such as blackeyed, are quite promising.

TABLE CII. VARIETY TEST OF COWPEAS, SULPHUR SPRING VALLEY DRY-FARM

Variety	Date planted	Stand	Date harvested	Yield per acre	
				Seed	Straw
1914		%		*Pounds*	*Pounds*
Whippoorwill	7–22	70	11–10	90	1800
1915					
Whippoorwill	4–23	80	10–16	188	968
"	5–12	80	10–16	231	924
White	7–22	90	10–22	195	400
Black-eyed	7–22	90	10–18	232	688

Watermelons: A garden plot of Tom Watson watermelons was planted July 19, 1915, and in October matured a very satisfactory yield of medium sized melons of good quality. See Table CIII.

TABLE CIII. MISCELLANEOUS TESTS, SULPHUR SPRING VALLEY DRY-FARM, 1915

Variety	Date planted	Date harvested	Yield per acre
			Pounds
Tom Watson watermelons	7–19	November	4800
Squashes	7–23	"	3200
Cantaloupes	7–19	"	....[1]
Peanuts	5–20	"	....[1]

1—Destroyed by rabbits.

Cantaloupes: Cantaloupes, planted July 19, 1915, germinated poorly and were destroyed by rabbits.

Squashes: Several varieties of squashes were planted July 23, 1915, all maturing before frost and yielding at the rate of 3200 pounds per acre.

Peanuts: A plot of peanuts was planted May 20, 1915, but rabbits ate them off as fast as they came up. They were quite persistent, however, and are interesting as a possible forage crop for Sulphur Spring Valley dry-farms.

Sweet Clover: A very few plants of sweet clover were produced in 1914. Three of these were transplanted, and in 1915 each yielded about one pound of seed. Sweet clover planted in 1915 failed entirely, due, largely, to drought in spring and a too loose seed bed.

Lespedeza: Lespedeza or Japanese clover was planted in the spring of 1915 but failed to germinate because of drought.

Vetch: Spring vetch produced but few inferior plants in both 1914 and 1915. Winter vetch was planted October 8, 1914, and gave promising results. The yield of approximately five tons of green forage per acre was plowed under for fertilizing purposes on June, 1915.

SUMMARY OF SULPHUR SPRING VALLEY DRY-FARM DATA

Alfalfa, grown in rows and cultivated, may be made to produce a fair crop of seed.

It is difficult to obtain a satisfactory stand of beans planted before the summer rains. Early varieties of beans may be planted

Fig. 46.—Dry-farmed late cowpeas. Grown near Cochise, Arizona.

in July, and a yield of 500 or 600 pounds per acre may be expected in a good season. Teparies have thus far been the surest and heaviest producers, but require protection from rabbits. Hopi lima beans are adapted to local climatic conditions but must be planted before the summer rains, since they require a fairly long season in which to mature. This usually necessitates some irrigation.

The improved American dent corn varieties produce fairly large amounts of feed and must be planted in the spring, the frost-free season following summer rains being too short to allow maturity. Early spring plantings may be made with a corn planter, but plantings in the drier months should be in lister furrows. The seed must be planted in moist soil. In a very dry season there is insufficient moisture and improper distribution of moisture to produce a successful yield of dent corns. Native Indian varieties and small American varieties may be successfully planted early in July, in case the summer rains have already begun.

The outlook for successfully growing small grains is not very promising. Wheat, planted early in the fall, will sometimes yield a fair crop, but little success has accompanied the growing of oats. The drought resistance of emmer and Red Winter speltz has been demonstrated on the Sulphur Spring Valley Dry-farm.

Sorghums are well adapted to Sulphur Spring Valley conditions. For the production of grain, Dwarf kafir, Dwarf milo, and feterita should be used, and, where forage is primarily desired, Dwarf kafir, Club-top, and Early Amber are the more promising varieties. Excellent results have been obtained from plots of Sudan grass.

In the light of experience to date, the most successful dry-farming rotation for the Sulphur Spring Valley is one consisting of grain sorghums, corn, Sudan grass and beans. Greatest profits are to be realized when dry-farming is combined with range stock raising. Managed in this way, a farm may be made to produce ensilage which may be kept for several years until a time of drought makes its use advisable, while crops of beans may be sold to furnish an income from time to time.

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